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Engineering Design Report

**THERMOELECTRIC ENVIRONMENTAL
CONTROL UNIT**

For

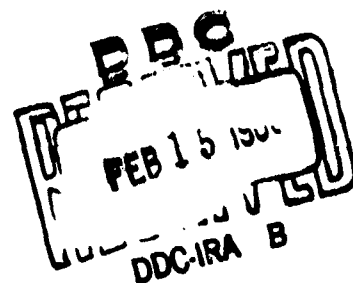
RESEARCH AND DEVELOPMENT PROCUREMENT OFFICE

U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES

FORT BELVOIR VIRGINIA

CONTRACT DA-44-009-AMC-1135(T)

TASK NO. 1D 643303 D54503



Carrier

Air Conditioning Company

MILITARY EQUIPMENT DEPARTMENT

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⑨ Final Engineering Design Report.,
for

⑥ THERMOELECTRIC ENVIRONMENTAL CONTROL UNIT.

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⑪ 27 Sep 65, ⑫ 100p

Prepared for

RESEARCH AND DEVELOPMENT PROCUREMENT OFFICE

U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES

FORT BELVOIR, VIRGINIA

⑬
Contract DA-44-009-AMC-1135 (T)

Task Order ID-643303 D54503
⑭

Submitted by

Military Equipment Department, Carrier Air Conditioning Company

Syracuse, New York

27 September 1965

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1.0 INTRODUCTION

1.1 General

This report is submitted in fulfillment of contract DA-44-009-AMC-1135(T) dated June 2, 1965. In accordance with the requirements of the contract, a detailed engineering design is provided for a 24,000 Btu/hr thermoelectric environmental control unit. The design has been formulated to meet the system requirements described in Exhibit "A", Purchase Description of Request for Quotation No. 65-1816-B dated January 5, 1965 and Amendment No. 1 dated April 26, 1965.

The design presented in this report is a practical one for the application. The analytical and design optimization techniques which are employed have been qualified by previous experience in designing and building thermoelectric systems. Useful experience which was utilized in this study includes the design and development of a thermoelectric air conditioning system for submarines, performed under contracts NObs 77112 and 84598 for the Bureau of Ships, U.S. Navy Department. More recently the first thermoelectric air conditioning and control systems to be sold for a commercial application were developed by Carrier for installation in the headquarters office building of S. C. Johnson and Son, Inc., Racine, Wisconsin. Twenty-eight complete systems have been in operation for approximately one year. The advantages and proven methods which were utilized in these systems have been incorporated into the environmental control unit design provided herein. The experience gained in these and other similar developments provides assurance that an actual system of the design shown can be built successfully and will perform in accordance with the operational characteristics described.

1.2 System Requirements

The Purchase Description calls for a complete engineering design of a thermoelectric environmental control unit to be optimized for minimum size and weight as well as for maximum efficiency. The design conditions for this system are detailed in the Purchase Description. A brief summary of the design conditions is listed in Table I:

TABLE I.

Cooling capacity	24,000 Btu/hr
Ambient air temperature	120°F
Supply air temperature	92°F
Coefficient of performance	Minimum of 1.0
Heating capacity	Unspecified, consistent with full reversal of design operating voltage
Maximum dimensions	40 in. wide x 18 in. deep x 66 in. high
Maximum volume	15 cubic feet
Supply air flow	840 to 1,000
Supply air pressure	0.25 in. of water
Control	Provisions for both automatic and manual operation
Power conversion	Solid state without voltage transformation
Main power supply	208 volt, 3 phase, adaptable to both 60 and 400 cps.
Reliability	Capable of continuous operating for 10,000 hours
Maximum noise level	ASHRAE NC-60

1.3 Proposed Work

On February 5, 1965 Carrier Proposal No. MD8512-2 was submitted to USAERDL in reply to the subject Proposal Request. This proposal detailed the work required to meet the specifications of the Purchase Description. No exceptions were taken to these specifications. The proposed work included a complete system analysis in order to provide an optimum design for the subject unit. This work has subsequently been completed as proposed; the exact procedure followed and the results obtained are described in the following sections of this report.

1.4 Summary of Work Completed

In order to formulate the system design, an extensive optimization analysis was carried out. In this analysis, twelve design parameters were optimized for minimum weight and maximum efficiency, four of which describe the TE panel configuration and eight which describe the heat exchanger characteristics.

Next, a study was made of the various system arrangements that could incorporate the optimized TE coil into a practical design which would meet the requirements of the purchase description. Consideration was also given to the type of fans which could be utilized with these various system arrangements. Similarly, various methods for controlling the system were studied. From the results of these studies, a final system design was developed as shown in Section 3.0 of this report. Further calculations were then made to determine the performance characteristics of this unit over a complete range of operating conditions. Performance information is contained in Section 4.3.

The system described in Section 3.0 is 28 inches wide by 18 inches deep by 63 inches high, weighs approximately 380 pounds, operates at an overall coefficient of performance (COP) of 1.12, and has a net cooling capacity of 24,000 Btu/hr at design operating conditions. The dual frequency vaneaxial fans selected for the design are well suited to meet the reliability and noise requirements. The power rectifier will furnish 3 phase, full wave d-c power without voltage transformation. The control system will furnish modulated capacity control from full cooling to full heating as required by the system load.

2.0 SYSTEM ANALYSIS

2.1 General

In order to make a complete system analysis, the environmental control unit was divided into three subsystems which, for convenience purposes, can be considered separately. These subsystems consist of the thermoelectric coil, the air handling system, and the control and power conversion system. The thermoelectric coil and the air handling system are very closely related physically. However, for purposes of design, the control and power conversion system may be considered to be independent of the other subsystems so far as physical interrelations are concerned. Some reasons for this include the small size, light weight, and high efficiency of this subsystem. Also, because this portion of the system is physically connected to the other parts by light flexible wire, it is not restricted in its physical location or orientation to the others.

2.2 Thermoelectric Coil

There are 14 major physical and operating parameters that affect the size, weight, and performance of an air-to-air thermoelectric unit. These are:

1. Element length
2. Element diameter
3. Element packing density (ratio of element area to panel area)
4. Conductor strap thickness
5. Operating current
6. Internal fin spacing
7. External fin spacing
8. Internal fin thickness
9. External fin thickness
10. Internal fin height
11. External fin height
12. Fin material
13. Internal air velocity
14. External air velocity

Because the thermoelectric coil is the heaviest part of the system, it is of considerable importance that this coil be optimized for minimum weight. The system fans also represent a substantial portion of the overall weight, the size and power requirements of which must also be included in this study in order to yield an optimum system. Fortunately, some of the system parameters do not require optimization. For example, the fin material must be aluminum, since it has the highest ratio of thermal conductivity to weight. Also, from past experience, it is known that the optimum strap thickness is considerably less than the minimum thickness that can be physically handled efficiently. The minimum conductor strap thickness is considered to be 0.020 inches for this system.

2.2.1 System Optimization Procedure. In order to optimize the remaining 12 parameters, equations were written which describe the system in terms of these parameters. These equations were then programmed into an analog computer and solved while each parameter was varied through a complete range of values. The results were then plotted to show variation in system coefficient of performance over a range of operating current density and for various values of the parameter being varied. An example of this plot is shown in Figure 1. This curve illustrates the significance of parameter variation since it shows the large change in performance that can be expected as a result of changes in internal air velocity. Not all of the parameters have this much effect on system performance or weight.

Fortunately, the optimum value of each parameter is somewhat independent of the others and; therefore, this procedure converges on an optimum design quite rapidly. To initiate this procedure, it was necessary to first assume a value for each parameter. Next, for each parameter, calculations were made over the complete range and the optimum parameter value was then used while the next parameter was varied. This procedure continued until all parameters were optimized the first time, then the entire procedure was repeated a second time to insure that all values represented the true optimum. Table II shows these parameters in the order they were optimized, the initial assumed parameter value, the parameter value after the first optimization, and the final value after the second optimization.

TABLE II

<u>PARAMETER</u>	<u>ASSUMED INITIAL VALUE</u>	<u>VALUE AFTER FIRST OPTIMIZATION</u>	<u>VALUE AFTER SECOND OPTIMIZATION</u>
Packing density (%)	--	50	50
Internal air velocity (ft/min.)	600	300	300
External air velocity (ft/min.)	1000	800	700
Internal fin spacing (fin/in.)	24	28	30
External fin spacing (fin/in.)	24	28	30
Internal fin thickness (in.)	0.010	0.007	0.006
External fin thickness (in.)	0.010	0.007	0.006
Internal fin height (in.)	1.00	0.80	0.80
External fin height (in.)	1.00	1.00	1.00

Some of the thermoelectric panel parameters are not shown in Table II. The element length is not included because this value was set up as a variable on the computer program and was varied to give the maximum coefficient of performance for each calculation (the element length was optimized for each solution). The other parameters not shown are element diameter and operating current. Indirectly, these values are combined into the current density and show up as one of the variables on the optimization curve, Figure 1. The element diameter is not actually optimized until the system design is finalized. Figure 2 shows the final results of this optimization procedure. This curve shows the optimum relation between system weight and system performance over the practical range of operating current density.

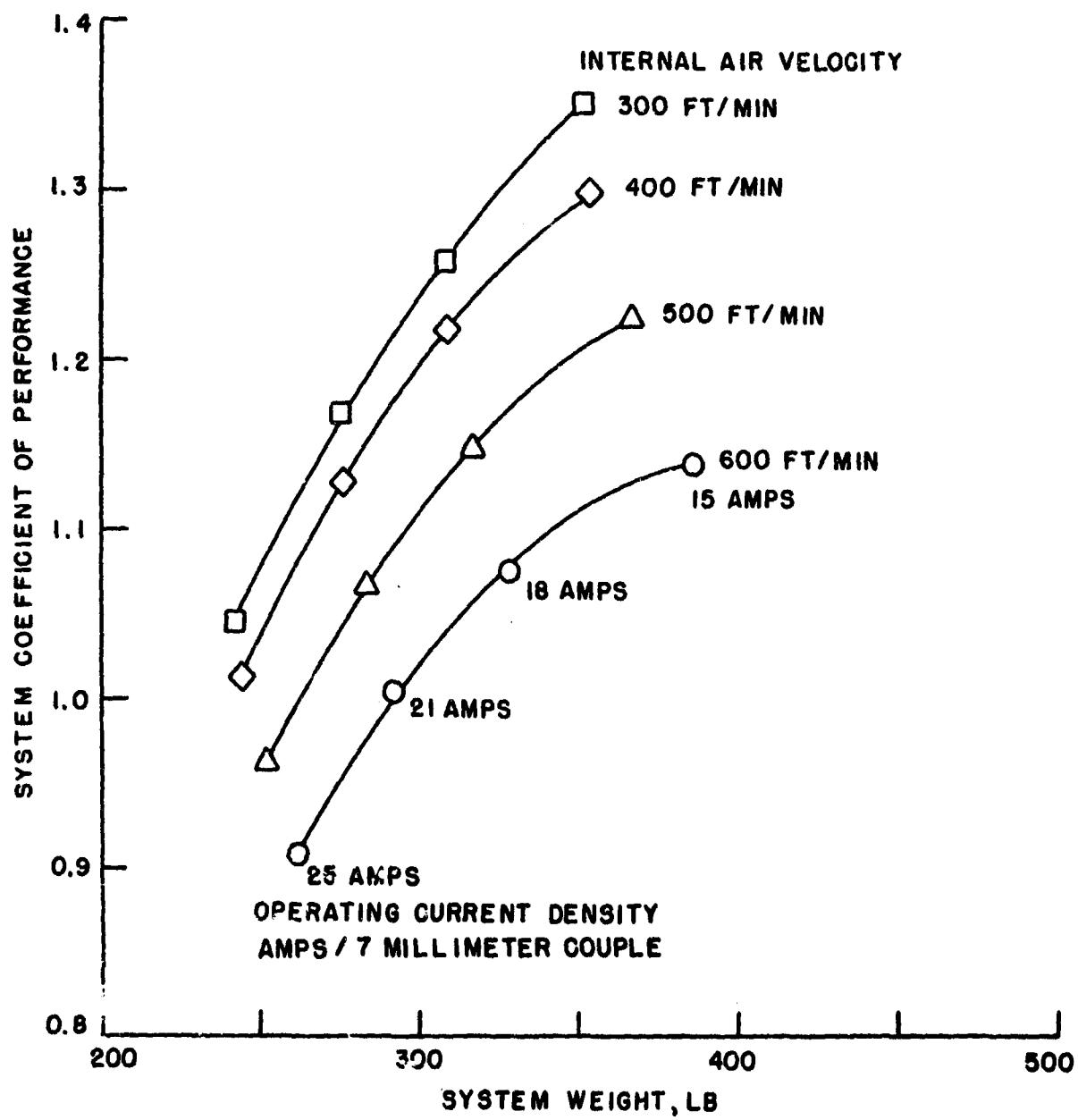


Figure 1. Optimization Curve Showing Weight and Performance over a Range of Internal Air Velocity

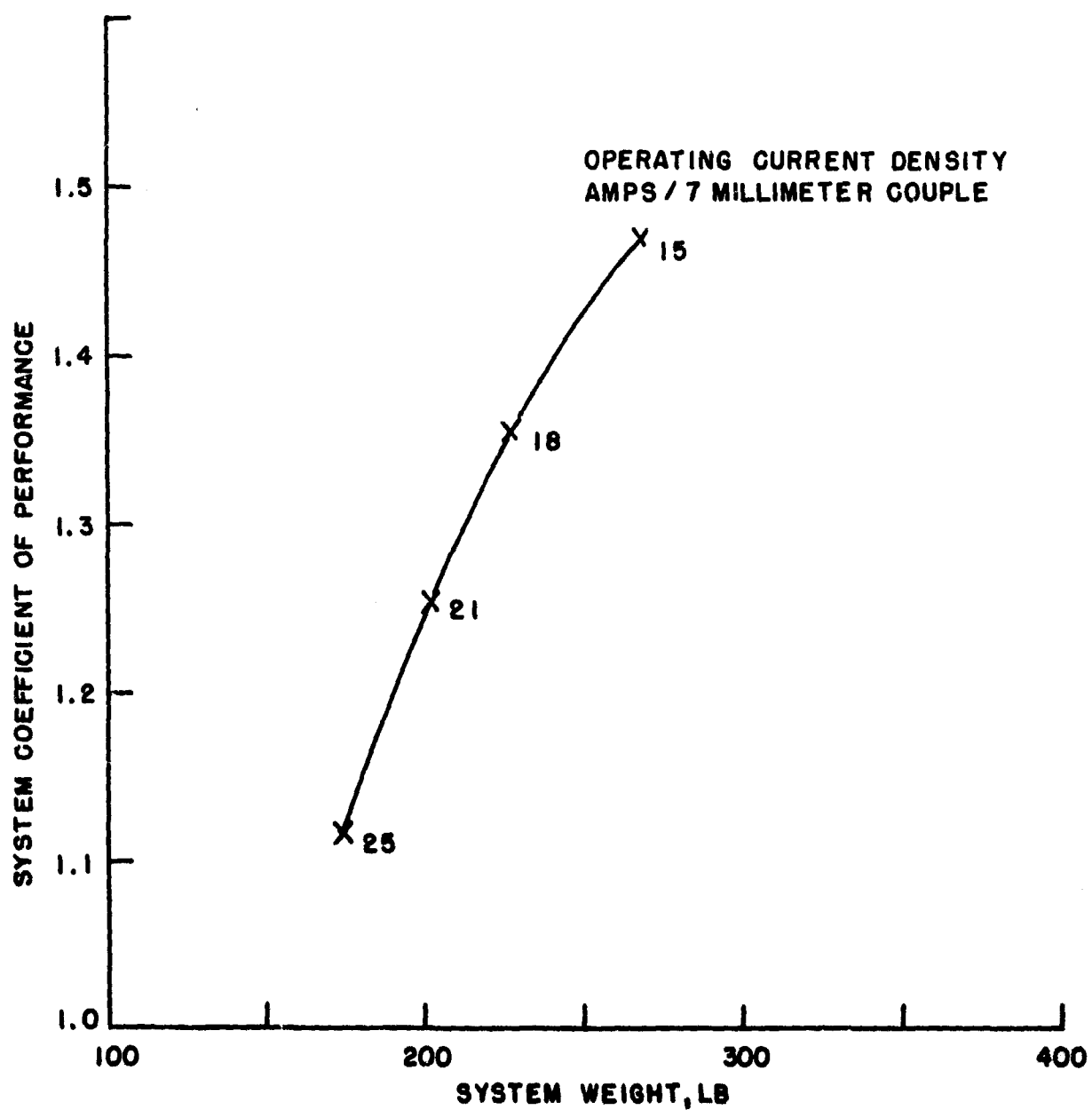


Figure 2. Final Optimization Curve showing System Weight and Performance as a Function of Current Density

It should be pointed out that in this study, reference is always made to overall system weight and system performance, not thermoelectric coil weight or performance. System weight includes the weight of the thermoelectric coil, the weight of the fans (which is calculated as a function of the fan power requirement) and the weight of the unit frame and manifolds which are assumed to equal 50 per cent of the fan and coil weight. System coefficient of performance is defined as the system cooling capacity divided by system power required. System power required includes fan power as well as the power required by the thermoelectric coil. Fan power is calculated from fin pressure drop and air velocity based on an overall fan-motor efficiency of 40 per cent. System cooling capacity is always equal to 24,000 Btu/hr, but is calculated by subtracting the internal fan power from the thermoelectric coil cooling capacity.

2.2.2. Analog Procedure. The optimization equations and the analog procedure used to solve these equations are essentially the same as those described in detail in Carrier's Proposal No. MD-8512-2. The exact equations and calculations are presented in the original design calculations attached to Copy No. 1 of this report.

2.2.3 Material Parameters. Thermoelectric material parameters used in this study are also the same as described in the reference proposal. These parameters represent average values obtained from actual measurement during fabrication of more than 600 thermoelectric panels built by Carrier, and are based on currently available commercial thermoelectric material. Table III shows the variation in material parameters with temperature.

TABLE III

PARAMETER	SYMBOL	UNITS	NUMERICAL VALUE	
			AT 81°F	AT 152°F
Seebeck coefficient	α	Volts/couple -°F	1.98×10^{-4}	2.18×10^{-4}
Electrical resistivity	$\rho_n + \rho_p$	Ohm-in./couple	7.84×10^{-4}	9.37×10^{-4}
Thermal conductivity	k	Btu-in./hr-ft ² -°F	7.72	7.84
Figure of merit	Z	°C	2.86×10^{-3}	2.86×10^{-3}
Electrical resistance of TE junctions	r	Ohm-cm ²	1×10^{-5}	1×10^{-5}
Thermal conductivity of foam insulation	k_{ins}	Btu-in./hr-ft ² -°F	0.20	0.20

Although these parameter values do vary with temperature, they were considered constant at the 152°F value for the optimization calculations. This is justified because the figure of merit is directly related to efficiency and this parameter does not vary with temperature over this range. It is important to note, however, that these variations are taken into account in the final design and the performance calculations described in Section 3.0 and Section 4.3.

The heat exchanger surfaces utilized in this analysis are a straight fin laminar flow type. The performance characteristics of these surfaces may be found in the original design calculations section.

2.3 Air Handling System

Optimization of the air handling system was accomplished to the greatest extent possible as described in paragraph 2.2.1. Other aspects of this subsystem which were further analyzed include fan efficiency, fan type, system noise level, and air manifold arrangement.

Fan efficiency has a definite relationship to fan type. If dual fans (two fans operating in parallel flow) are used for both the internal and external air streams, these fans would operate at specific speeds of 82,500 and 88,000 respectively:

$$[\text{specific speed} = (\text{rpm}) (\text{cfm})^{1/2} / (\text{inch water pressure})^{3/4}]$$

These specific speed ranges represent an efficient operating condition for vaneaxial type fans. If it were desirable to use forward-curved, squirrel-cage type blowers; two double-inlet scrolls or four single-inlet units should be used. It was estimated that the overall fan-motor efficiency of the vaneaxial units would be twice that of the squirrel-cage units. Other type blowers available were not considered to be feasible for this system.

In order to meet the dual frequency requirement, it is necessary that fan motors operate at both 60 and 400 cps. Dual frequency motors are available with separate windings within the same motor frame. Also, statically commutated motors have recently been developed which will operate on either frequency; however, information obtained from the manufacturers indicate that these motors are not sufficiently developed to be considered at this time. Thus, it appears that the dual frequency motors are best suited for this application. With these motors, it will be necessary to connect the power to the proper winding terminals depending on the power supply frequency.

With respect to system noise level, it appears that the NC-60 requirement could be met using either type of blower considered. Typically a squirrel-cage blower will generate the greatest noise in the low octave bands where the human ear is less sensitive. Although the vaneaxial fan generates the highest noise levels in the center octave bands, this noise is more readily attenuated with acoustical insulation. In this system, one inch thick fiberglass insulation will be used wherever it will effectively absorb sound or decrease thermal conduction losses.

Probably the most important consideration related to the air handling system is the manifold arrangement. This, in conjunction with the type and number of fans used, largely dictates the size and shape of the overall unit. The possibility exists that the manifolds could be eliminated by going to a cross-flow coil design; however, this presents other problems. In a crossflow design, the coil must be shallow in two directions in order to keep the fan pressure requirements at a reasonable level. Making the coil shallow in two directions on a system of this size results in a long thin coil which is difficult to design into a system. A counterflow coil, being shallow in only one direction, does not have this limitation.

In order to obtain a good manifold arrangement, five possible systems were sketched out and the advantages and disadvantages of each were considered. Systems 1, 2, and 3 were relatively short and wide. A combination of squirrel-cage and vaneaxial fans were used in System 1. System 2 was similar except that it used only vaneaxial fans. System 3 used vaneaxial fans in a somewhat different arrangement than System 2. The major disadvantages of all three systems was large size and poor fan and manifold air entrance arrangements. System 4 was a relatively high and narrow arrangement using all vaneaxial fans. This system was smaller and had considerably better air flow arrangements than the other three systems. From this arrangement it became obvious that System 4 could be made shorter by increasing the coil depth slightly. System 5 includes this change which saved 12 per cent in system volume and 20 per cent in manifold length. The penalty for this saving was a 20 per cent increase in fan power resulting in a three and one-half per cent decrease in system coefficient of performance.

System 5 was then selected as the best fan and manifold arrangement to be incorporated into the final design. The advantages of this system arrangement are pointed out in Section 3.0 of this report.

2.4 Control and Power Conversion System

The object of the control and power conversion system is to regulate d-c power to the thermoelectric coil in response to a signal obtained from the temperature sensor. In order to provide this power regulation, two step-control methods and five proportional-control methods were considered. The criteria used to evaluate these methods were size, efficiency, reliability, degree of modulation, and cost.

The first method considered was a switching scheme whereby the total current through the thermoelectric coil could be increased in discrete steps by automatically reconnecting the thermoelectric modules from a series to a parallel circuit. The main objection to this method is the increased cost of the coil, since a proportionately larger number of smaller couples would be required if the unit were to operate at full capacity with the modules connected in parallel. Transforming the power to a lower voltage would solve the problem mentioned above, but this could be accomplished only at the expense of transformer weight and power loss. In addition, the specifications stated that power conversion should be accomplished without voltage transformation.

A simple two-step control was considered whereby the voltage to the coil would be increased by switching from half-wave to full-wave rectification. The limited degree of modulation attainable, which in turn affects the system efficiency, is the main disadvantage of this method. Also, a special power generator would be necessary in order to operate on half-wave power.

The five types of proportional control systems that were considered include: (1) motor-generator set; (2) magnetic amplifier and rectifier; (3) servo-driven variable transformer; (4) thyatron bridge; (5) silicon controlled rectifier bridge. SCR's and thyatrons can be used in circuits other than the bridge circuits to accomplish proportional power conversion; however, the bridge circuit is more efficient and requires fewer power components.

The SCR bridge control method is easily the best of those considered above. The reasons for this largely involve the small size, high efficiency, and low cost of this system. Reliability information on SCR systems is incomplete at this time, but experience to date indicates this method is at least as reliable as any of the other methods considered. On this basis, the SCR full-wave bridge method was used in the final system design.

3.0 SYSTEM DESIGN

3.1 Thermoelectric Coil

The final design of the thermoelectric environmental control unit was largely dictated by the results obtained from the system analysis. However, in order to make this design realistic, experience and engineering knowledge require that numerical values obtained from the computer study be somewhat compromised.

It has been well substantiated that there are cooling capacity losses in this type system that are very difficult to calculate. This includes such losses as air leakage, joule heating in electrical wires and connectors, structural heat conduction, ductwork and manifold conduction, thermoelectric material parameter variation, and non-uniform air flow distribution. Added together, these losses equal nearly ten per cent of the system cooling capacity. Consequently, for a net capacity of 24,000 Btu/hr, the system should actually be designed for a capacity of 26,400 Btu/hr. Figure 3 shows the relationship between system weight and system performance when this ten per cent loss factor is included.

As mentioned in paragraph 2.2.1, the relationship between operating current and element diameter must be such that the system will operate at 278 volts. A graphical method shown in Figure 4 was used to determine this relationship. As shown on this graph, a single line represents the relationship between operating current, d-c power and voltage (design voltage = 278 volts d-c). The diagonal lines which cross the voltage line represent the relationship between current and power for systems made up of various diameter elements. The vertical lines show the approximate relationship between system coefficient of performance and d-c power draw. Thus, a system COP of 1.20 may be obtained by using 7.3 millimeter diameter elements and the system should operate at 18.0 amperes.

More exact calculations of the system performance later determined that the element diameter should be 6.9 mm. and the system should operate at 17.5 amperes. Reasons for this deviation from the optimum result include:

- (1) Thermoelectric material parameters were considered to be independent of temperature for the optimization calculations.
- (2) Changes in coil depth and air flow velocities were made in order to compact the system as described in paragraph 2.2.

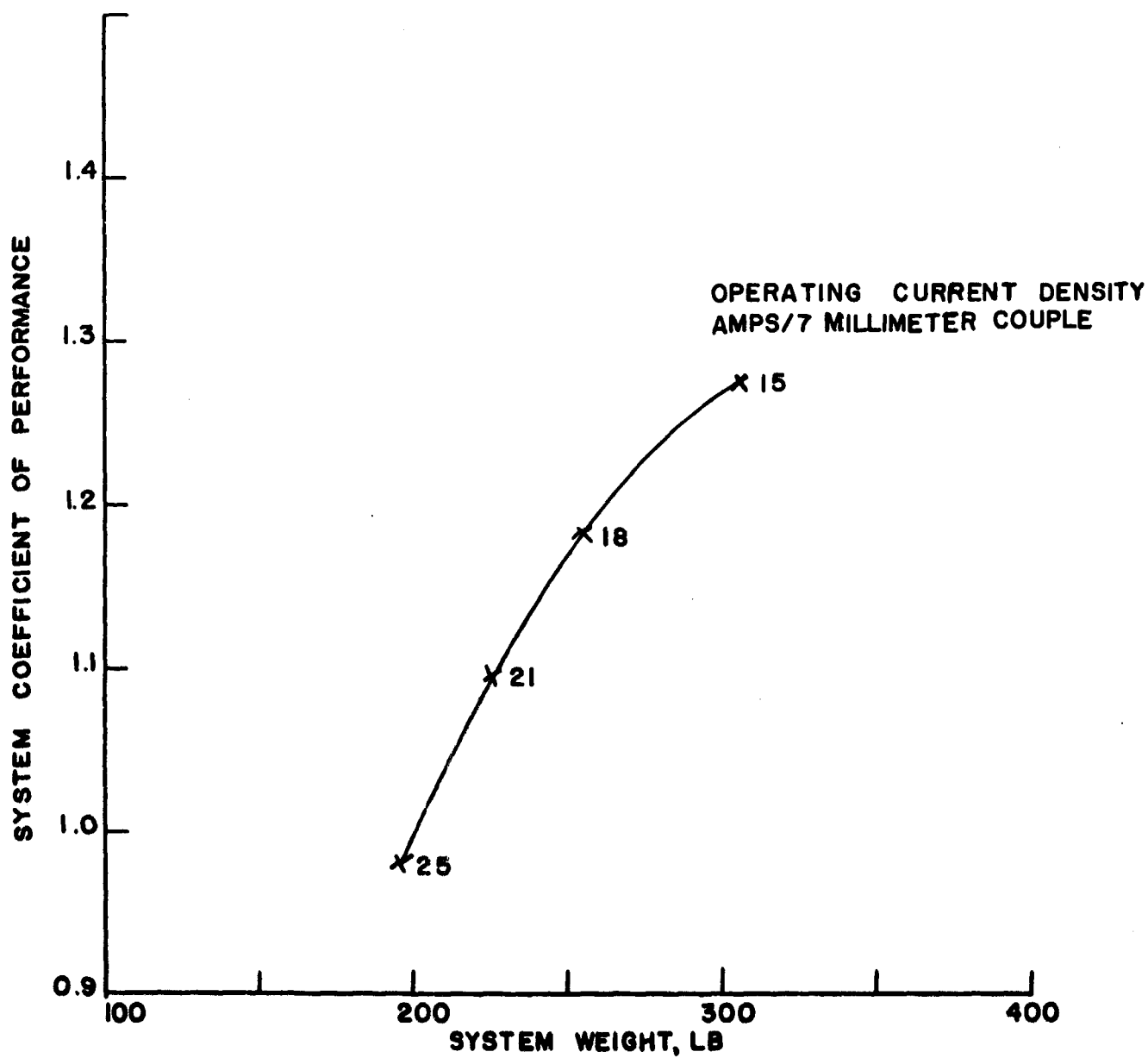


Figure 3. Design Curve Showing System Weight and Performance
when 10 Per Cen. Capacity Losses are Included

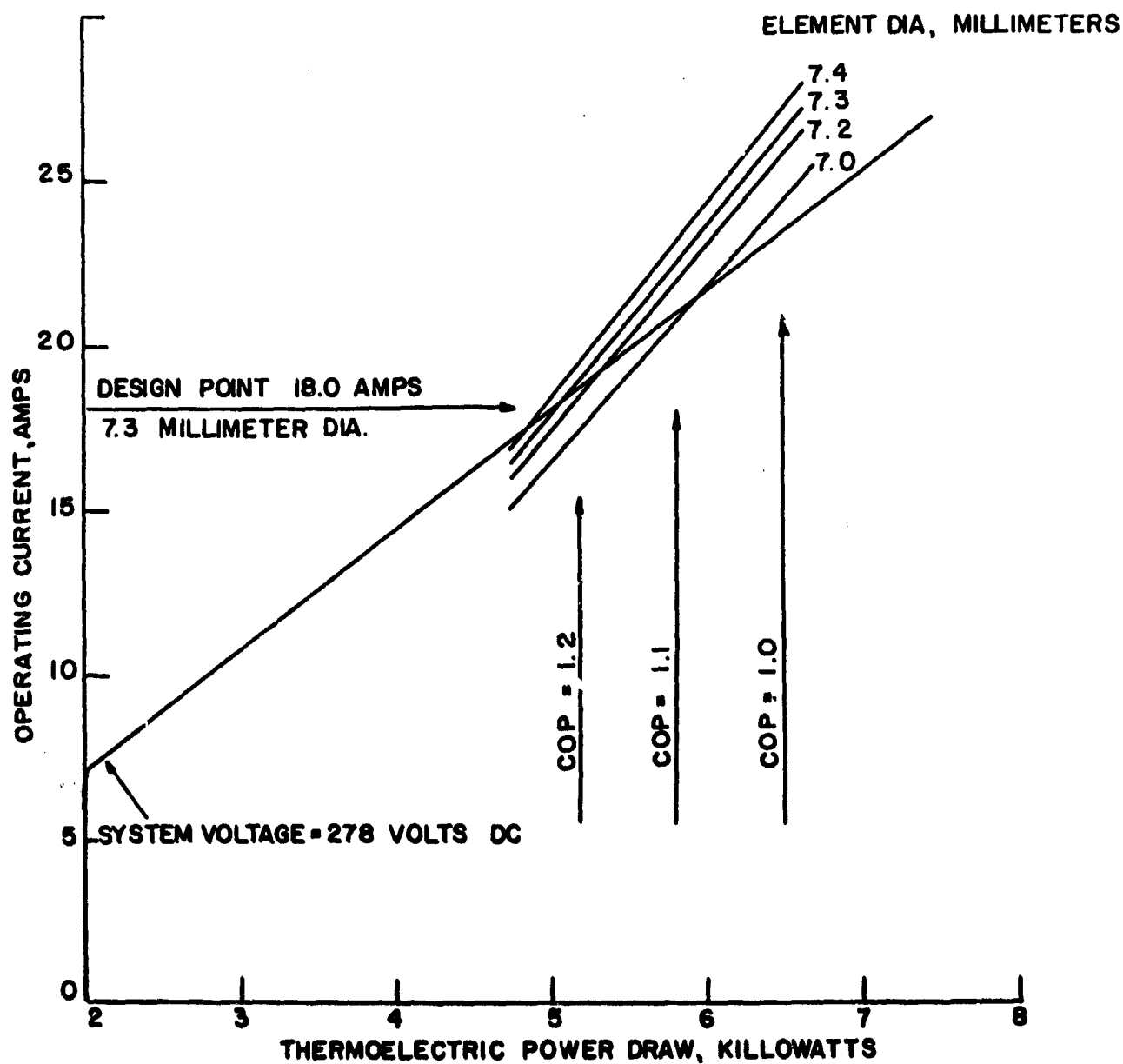


Figure 4. Graphical Determination of Thermoelectric Element Diameter

3.2 Control and Power Conversion

Although the system analysis determined that an SCR full-wave bridge would provide the best means of supplying power to the thermoelectric coil, a number of considerations must be taken into account before the exact control and power conversions circuit is finalized. The power conversion is accomplished with a 3-phase bridge capable of supplying approximately six kilowatts of d-c power when operated from a 208 volt, 60 or 400 cycle supply. After full-wave rectification and allowing for a 2.5 volt drop across the SCR's, the 208 volt a-c supply converts to 278 volts d-c. The magnitude of the d-c voltage can be controlled by controlling the conduction time of the SCR's. Thus, the main problem was to design the necessary circuitry to control the SCR conduction time in proportion to the deviation from the system set point temperature. Also, the polarity of the output voltage must be reversed as the heat pumping requirement changes from heating to cooling and vice versa. Additional circuitry must be designed for manual operation as well as for over-temperature protection.

Automatic reversing could be accomplished statically by using 12 SCR's in the bridge, or by using a double pole, double throw relay in conjunction with a bridge containing three SCR's and three diodes. The relay method was used because of its simplicity.

The control circuitry includes a firing circuit, a signal shaping network, an amplifier, a temperature sensor and a Schmitt trigger. The Schmitt trigger is used to convert the analog signal from the temperature sensor to a digital signal for operating the reversing relay.

The temperature sensor consists of a thermistor connected in a d-c bridge. The voltage signal from the bridge is proportional to the resistance of the thermistor. The amplifier is required to increase this signal to a workable level.

The signal shaping network is required to provide a dead zone about the set point temperature and also to provide a 180 degree phase shift in the amplifier voltage signal when cooling is required.

The firing circuit controls the conduction time of the SCR's. The SCR's are non-conducting until voltage pulses from the firing circuit are supplied to the SCR gates, at which time conduction begins and continues until the end of a cycle.

Transistors and other semiconductor devices used in this circuit have characteristics which vary with temperature. Therefore, the circuit is temperature compensated so that temperature change of the control components will not affect the operation of the unit.

A diode bypass of the SCR's is used for manual operation. A relay connects three diodes into the bridge in place of the three SCR's. All of the automatic circuitry is bypassed and maximum power will be supplied to the heat pump.

A thermistor over-temperature protection network was designed to protect the thermoelectric modules from excessively high temperatures that might result from a fan failure. If a thermistor detects a high temperature condition, power to the thermoelectric modules is removed.

A radio frequency filter was designed and is used in the system for suppression of interference which will be introduced by the switching of the SCR's.

The use of a filter for reducing the ripple at low output voltage was studied. The results of the study indicated that the filter was not worth the extra weight it would add to the system.

3.3 Design Details

The physical system configuration and the design system performance are outlined below:

3.3.1 Physical Configuration

a. Thermoelectric Panels

Element length, 0.087 inch
 Element diameter, 6.9 mm.
 Element packing density, 0.45
 Conductor strap thickness, 0.020 inch
 Number of couples, 34 per panel
 Panel size, 3.625 x 2.540 x 0.177 inches

b. Heat Exchangers

<u>Parameter</u>	<u>Internal HX</u>	<u>External HX</u>
Fin spacing, fin/inch	30	30
Fin material	Aluminum	Aluminum
Fin thickness, inch	0.006	0.006
Fin height, inch	0.80	1.00
Size, inches	5.25 x 7.37 x 0.94	5.25 x 7.37 x 1.04

c. Thermoelectric Modules

Number of TE panels per module	4
Number of TE couples per module	136
Number of heat exchanges per module	1 internal, 1 external
Size	5.25 x 7.37 x 2.06 inches
Weight	2.67 lb

d. Fans

<u>Parameter</u>	<u>Internal</u>	<u>External</u>
Manufacturer	General Dynamics	General Dynamics
Type	Vaneaxial	Vaneaxial
Identification	Proposal No. RA-5519	Proposal No. RA-5520
Model No.	9071-A	9092-A
Length, inches	7-1/4	10-1/8
Diameter, inches	8-3/4	11
Weight, lb	13-1/2	28

e. Control and Monitor Panel

Size	14 x 13 x 4 inches
Weight	5 lb

f. Control and Power Conversion Package

Size	20 x 8 x 4 inches
Weight	16 lb

g. Complete Thermoelectric System (24,000 Btu/hr)

Number of TE modules	60
Number of TE panels	240
Number of TE couples	8160
Number of internal fans	2
Number of external fans	2
Overall size	18 in. deep x 28 in. wide x 63 in. high
Overall volume	18.4 cubic feet
Overall weight	380 lb

3.3.2 System Performance (Design Point Operation)

a. Thermoelectric Coil

	Main Power Supply Frequency	
	60 cps	400 cps
Current, amperes d-c	17.5	17.7
Voltage, volts d-c	278	278
Power draw, kilowatts	4.86	4.92
Cooling capacity, Btu/hr	28,050	28,230
Coefficient of performance	1.69	1.68
Internal air velocity, ft/min	359	402
External air velocity, ft/min	838	945

b. Internal Fan, Each Unit

	60 cps	400 cps
Voltage, volts a-c	208	208
Phase	3	3
Current, amperes a-c	0.6	1.5
Power factor	0.85	0.51
Motor efficiency	0.65	0.57
Brake horsepower, hp	0.16	0.21
Power draw, watts	184	275
Sound pressure level, C-scale	70	70
Guaranteed life, hr	3,000	3,000
Expected life, hr	20,000	20,000
Air flow, cfm	510	560
Air pressure, in. of water	1.26	1.43

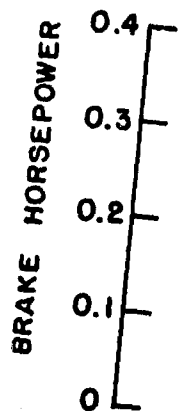
c. External Fans, Each Unit

	Main Power Supply Frequency	
	60 cps	400 cps
Voltage, volts a-c	208	208
Phase	3	3
Current, amperes a-c	2.4	5.3
Power factor	0.90	0.57
Motor efficiency	0.70	0.63
Brake horsepower, hp	0.73	0.92
Power draw, watts	780	1090
Sound pressure level, C-scale	80	80
Guaranteed life, hr	3,000	3,000
Expected life, hr	20,000	20,000
Air flow, cfm	1260	1380
Air pressure, in. of water	1.75	2.00

d. Complete System

	60 cps	400 cps
Voltage, volts a-c	208	208
Current, amperes a-c	19.7	24.4
Power factor	0.99	0.89
Phase	3	3
Power draw, kilowatts	6.84	7.70
Cooling capacity, Btu/hr	26,230	25,800
Overall coefficient of performance	1.12	0.98

Performance curves for the internal and external fans are shown in Figures 5 and 6, respectively. These graphs also show the system characteristic curves.



GENERAL DYNAMICS/ELECTRO DYNAMIC
MODEL - 9071A
DENSITY - .075 LB/FT³
SPEED AS INDICATED

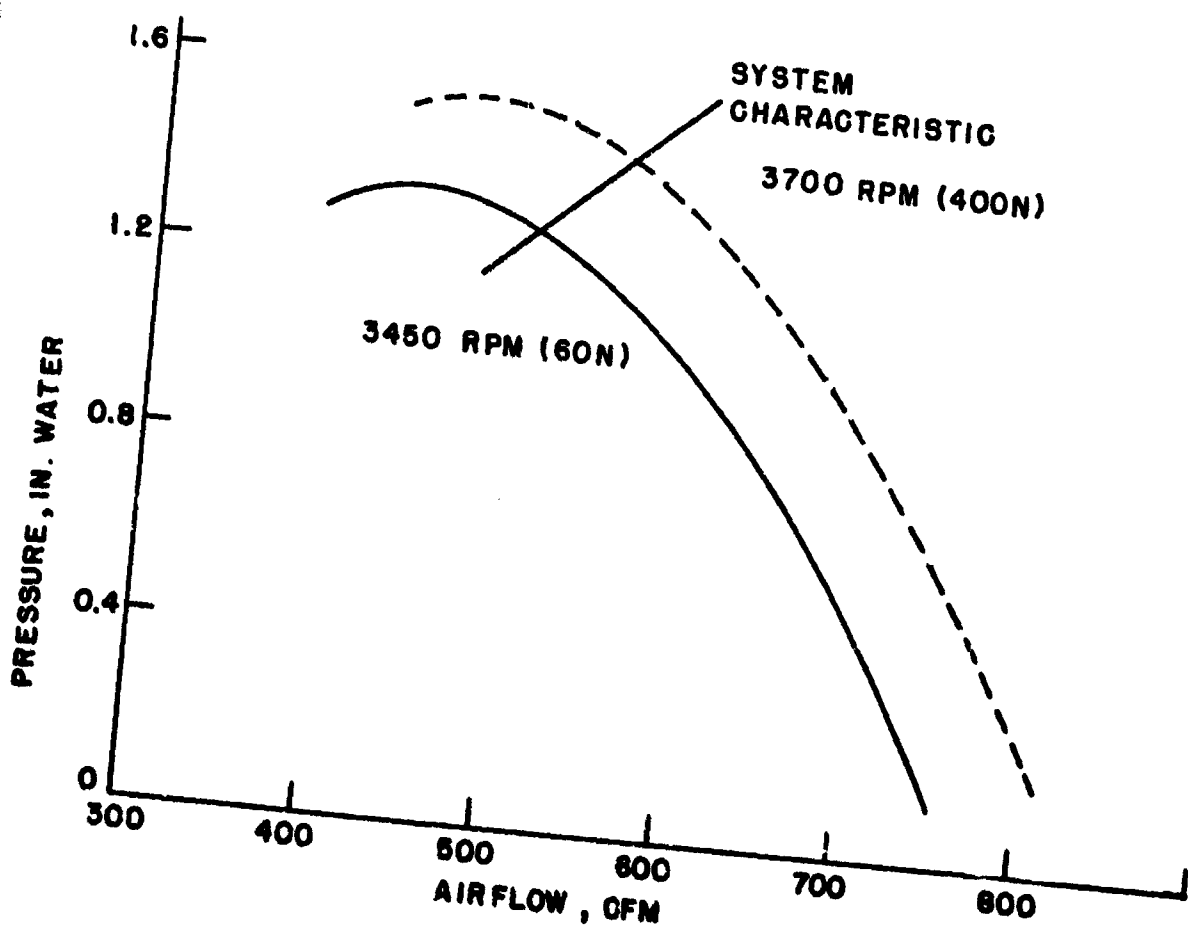


Figure 5. Internal Fan Performance

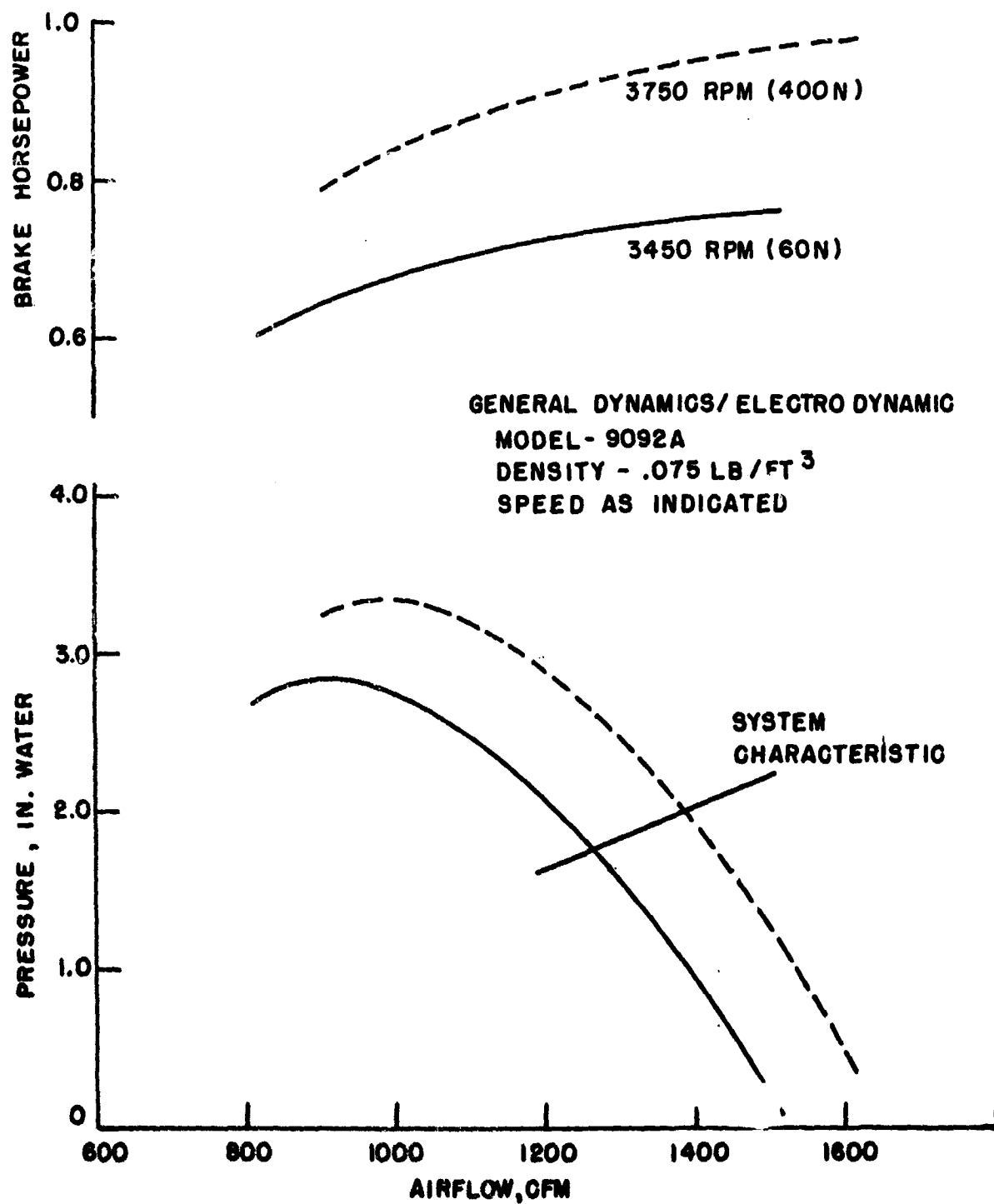


Figure 6. External Fan Performance

3.4 Design Drawings

Detailed engineering drawings are included in Appendix A. Most of these are assembly drawings, and the appropriate bill of material for each assembly is shown on the drawing. Exact design details for all special components which are pertinent to the operation of the system are also shown on these drawings.

Drawing number R-1058-3429 shows a thermoelectric panel assembly. In operation, the electrical current will feed into the panel through one of the insulated lead straps then alternately through the n-type and p-type bismuth telluride elements and out the insulated lead strap at the opposite end of the panel. The 34 pairs of elements in each panel are connected in series by means of the 67 insulated conductor straps. The insulated conductor straps are made of a metalized ceramic wafer soldered between a copper conductor strap, and a copper spacer. This sandwich assembly has a dielectric breakdown strength in excess of 4000 volts d-c, and an electrical resistivity in excess of 10^{12} ohms.

Drawing number R-1058-4430 shows how four of the thermoelectric panels are soldered in place between the aluminum internal and external air heat exchangers to form a module assembly. This module assembly is the basic building block of the thermoelectric coil. In the complete system, 60 of these modules are stacked in 12 side-by-side banks, each bank five modules high. The current flows through two panels on one side of each module in series, then on through the two panels on the same side of the next module located directly above the first, and so on through the five modules in one bank to the top of the bank. At the top, current flows through a jumper strap to the panel located on the opposite side of the top module and then back down through the same five modules. At the bottom of each bank the current will flow to the next bank of modules and so on in series through all 12 banks.

Drawing R-1058-9434 shows the unit framework assembly. The frame is constructed from $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$ inch aluminum angle and $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{8}$ inch square aluminum tubing welded together. Calculations determined that this size angle would keep the natural frequency of the long structural members well above the rotational frequency of the system fans. Item 26 of this drawing is the internal air supply manifold. These manifolds, as well as the return manifolds, are formed from aluminum sheets insulated with a $\frac{3}{16}$ inch layer of free foamed epoxy prior to cutting and forming.

Drawing R-1058-9431 shows the system control and monitor panel. This panel mounts into a sealed, recessed compartment on the inside face of the unit such that it may, if desired, be remotely located without resealing the opening from which it was removed. Electrically, this panel is connected to the unit by a single feed-through connector mounted near the bottom of the recessed compartment wall. The system temperature sensor mounted on the face of this panel is detailed on drawing R-1058-3432.

Drawing R-1058-9433 shows the power conversion and control package. This package is made up of a two-compartment box designed to confine radio frequency noise generated by the silicon control rectifiers. The free convection fins mounted to the outside of this box are designed to conduct heat away from the power rectifier which is mounted directly adjacent to the fins on the inside of the box. The rectifier mounting blocks are in good thermal contact with the aluminum box, but are electrically insulated from the box by 18 electrically insulated ceramic conductor straps.

Drawing R-1058-4435 shows the access cover assembly. This removable cover mounts on the outside face of the unit and is easily removed to allow access to the thermoelectric modules, the internal and external fans and the power rectifier and control package. A fine mesh wire screen prevents dust and dirt from entering the external air inlet, and the outer grill protects the unit from damage. The internal air return manifolds are mounted to the cover such that when the cover is tightened down, it will hold the thermoelectric modules firmly in position.

Drawing R-1058-9436 shows six views of the complete environmental control unit along with a sectional side elevation. This drawing shows the mounted location of all the system components described above. The buss-bar which carries the electrical current from one bank of modules to the next is detailed in drawing R-1058-3437.

Drawing R-1058-9439 shows a pictorial side elevation of the unit indicating the flow paths of the internal and external air streams.

3.5 Electrical Circuit Diagram

Drawing R-1058-4428 shows the schematic wiring diagram for the system. As shown, the 3-phase, 208 volt, 60 or 400 cycle power feeds into the unit through the main power circuit breaker switch (CB1), through the power rectifier, through the reversing relay (RR), and to the thermoelectric heat pump. Lead wires connect the module selector switch to each of the 12 banks of thermoelectric modules so that the voltage drop across each individual module bank, or across the total coil, may be monitored on the voltmeter (VM).

The same input power feeds through the fan power circuit breaker (CB2) to the internal and external fans, as well as to the control system voltage transformer (TRANS.1). The automatic control network is made up of a temperature sensor circuit, amplifier, Schmitt trigger, signal shaping circuit, and firing circuit. This network picks up a signal from the temperature sensor thermistor (TH1) and feeds a control signal through the pulse transformers (PT1, PT2, PT3) to the gates of the silicon control rectifiers (SCR1, SCR2, SCR3). At the same time, the Schmitt trigger controls the operation of the control relay (CR1) which in turn operates the reversing relay (RR). The system selector switch (SW1) bypasses the automatic control network when it is in the manual heat or manual cool position. In the manual position, the reversing relay and the power rectifier circuit are controlled such that the unit may operate at either full cooling or full heating. During manual operation, the power to the thermoelectric coil bypasses the SCR's and is supplied through the power diodes (D4, D5, D6). The over-temperature protection circuit monitors the signal from the over-temperature thermistors (TH2, TH3, TH4, TH5), and will cut off the power to the rectifiers by operating the control relay (CR2) which in turn will open the main contactor (MC). The over-temperature thermistors are mounted to the thermoelectric coil frame so that they are in good thermal contact with the internal and external air fins.

3.6 Design Requirements

The design requirements for this system are specified in Section 2 of the Purchase Description as amended by Amendment No. 1. The system design described in Sections 3.2, 3.3, and 3.4 above meets or exceeds all of the specified requirements with the exception of unit volume. The 18.4 cubic foot volume of this design exceeds the 15 cubic foot requirement described in Section 2.2.3 of the Purchase Description.

With regard to certain requirements describing the method of control, variations are made in the exact method specified. However, the same end result is accomplished by means that are considered better than those described. These variations are described below; the section numbers listed refer to those used in the Purchase Description.

Section 2.4.2.2 - Automatic Capacity Control:

With this system design, automatic capacity control is accomplished by modulating the voltage applied to the thermoelectric coil. This modulation is continually proportional from full cooling to full heating. The operation of this control system is described in more detail in Section 4.1.3.3 of this report.

Section 2.4.3.1 - Selector Switch:

The selector switch has only three positions: MANUAL HEAT, MANUAL COOL, and AUTOMATIC.

Section 2.4.3.1.3 - Off:

Power to the thermoelectric coil is turned off by turning the main power circuit breaker switch to the OFF position.

Section 2.4.3.1.5 - Start:

A special start mode of operation is not provided. With the fast response time and the high heat pumping capacity of a thermoelectric unit during start-up, it appears that a special starting mode of operation should not be required.

Section 2.4.3.2.1 - Inside Fan Motor Switch:

The inside fan will run whenever the fan power circuit breaker switch is on.

Section 2.4.3.2.2 - Outside Fan Motor Switch:

The outside fan motor switch has two positions, ON and AUTOMATIC. The system could possibly be damaged if the external fans were turned off when the unit was operating in the cooling mode, consequently the OFF position was eliminated.

Section 2.4.3.5 - Monitor Lights:

A voltmeter and a thermoelectric module selector switch are located on the control and monitor panel. This provides a means of checking the exact voltage drop across each module bank.

Section 2.4.7 - Thermoelectric Modules:

This unit has 12 module banks each comprised of five identical modules.

4.0 SYSTEM OPERATION

4.1 Description of Operation

4.1.1 General. The basic subsystems comprising the thermoelectric environmental control unit are: (1) thermoelectric coil, (2) air handling, and (3) control and power conversion.

Referring to Drawing R-1058-9439, the air flow paths through the fans, manifolds, and thermoelectric coil are shown. Internal air enters the top of the unit just above the internal fans and passes through the fans into the internal air supply manifolds. It then passes through the thermoelectric coil, up through the six return air manifolds and leaves the unit through the top opening near the outside face of the unit.

External air enters through the outside face of the unit, passes through the protective grill and fine mesh screen straight into the external air fins of the thermoelectric coil. After leaving the coil, air passes downward into the external fans and is discharged through a protective grill near the bottom of the outside face. Thus, the two air streams pass through the coil in counter flow. The internal circuit is under positive pressure and the external circuit under negative pressure so that any air leakage will always be from the internal to the external air stream.

The direction of heat flow through the thermoelectric modules is dependent on the polarity of d-c power supplied to the modules. In the cooling mode, heat is pumped from the internal air stream to the external air stream. In the heating mode, heat is not actually extracted from the external air stream, since the external fans are always off. However, the heat equivalent of the power input is rejected to the internal air stream. Control of the d-c current flow quantity and direction is described in Section 4.1.2.

4.1.2 Control and Power Conversion

4.1.2.1 Manual Operation.

Refer to Drawing R-1058-4428. When the system selector switch (SW1) is in the manual cool position, the manual relay (MAN) is energized, the SCR's (SCR1, SCR2, SCR3) are disconnected from the rectifier bridge, and the diodes (D4, D5, D6) are connected to the bridge. The reversing relay (RR) is in the non-energized cooling position and 278 volts d-c is applied to the thermoelectric heat pump.

With the system selector switch in the manual heat position, manual relay (MAN) is again energized, the reversing relay (RR) is energized to the heating position, and 278 volts d-c is applied to the thermoelectric coil. Also, the fan relay (FR) is energized, cutting the external fans off.

4.1.2.2 Automatic Operation.

In the automatic mode of operation, a small voltage signal is produced by the temperature sensor in proportion to the difference between the set point temperature and the temperature of the control thermistor (TH1). The resistance of the thermistor decreases as the temperature increases, and this causes the voltage at the base of transistor TR1 to increase in proportion to the temperature increase. The voltage signal is amplified by transistor TR2 and then supplied to the reversing network consisting of a Schmitt trigger, a control relay (CR1), and the reversing relay (RR). Simultaneously, this amplified signal is supplied to the signal shaping network.

The amplifier and Schmitt trigger are biased so that the reversing occurs at a set point temperature of 67°F. As the temperature rises above 67°F, the control relay (CR1) is energized, opening its normally closed contacts. Also, the reversing relay is de-energized placing a cooling polarity on the thermoelectric coil, and the fan relay (FR) is de-energized turning on the external fans. As the temperature of the control thermistor drops below 67°F, the control relay (CR1) is de-energized which in turn energizes the reversing relay to the heating position, and the fan relay turns off the external fans.

The signal shaping network provides a dead zone of $\pm 5^\circ\text{F}$ about the set point temperature. When the control thermistor temperature is in this dead zone, no signal is supplied to the firing circuit, and consequently power is not supplied to the thermoelectric coil. As the control thermistor temperature increases above 72°F, the voltage from the signal shaping network increases continuously until the full cooling signal is produced at 77°F. Conversely, as temperature drops below 62°F, the voltage decreases until the full heating signal is produced at 57°F.

The voltage from the signal shaping network is supplied to the firing circuit which controls the conduction time of the SCR's in proportion to the voltage signal. Controlling the conduction time of the SCR's in turn controls the voltage applied to the thermoelectric coil. Figure 7 shows the relation between the control thermistor temperature and the applied system voltage. The firing circuit used here is a unijunction type. In this circuit, a voltage signal is converted to a time signal by charging a capacitor. Thus, a high signal voltage corresponds to a short charging time which in turn results in a long conduction time.

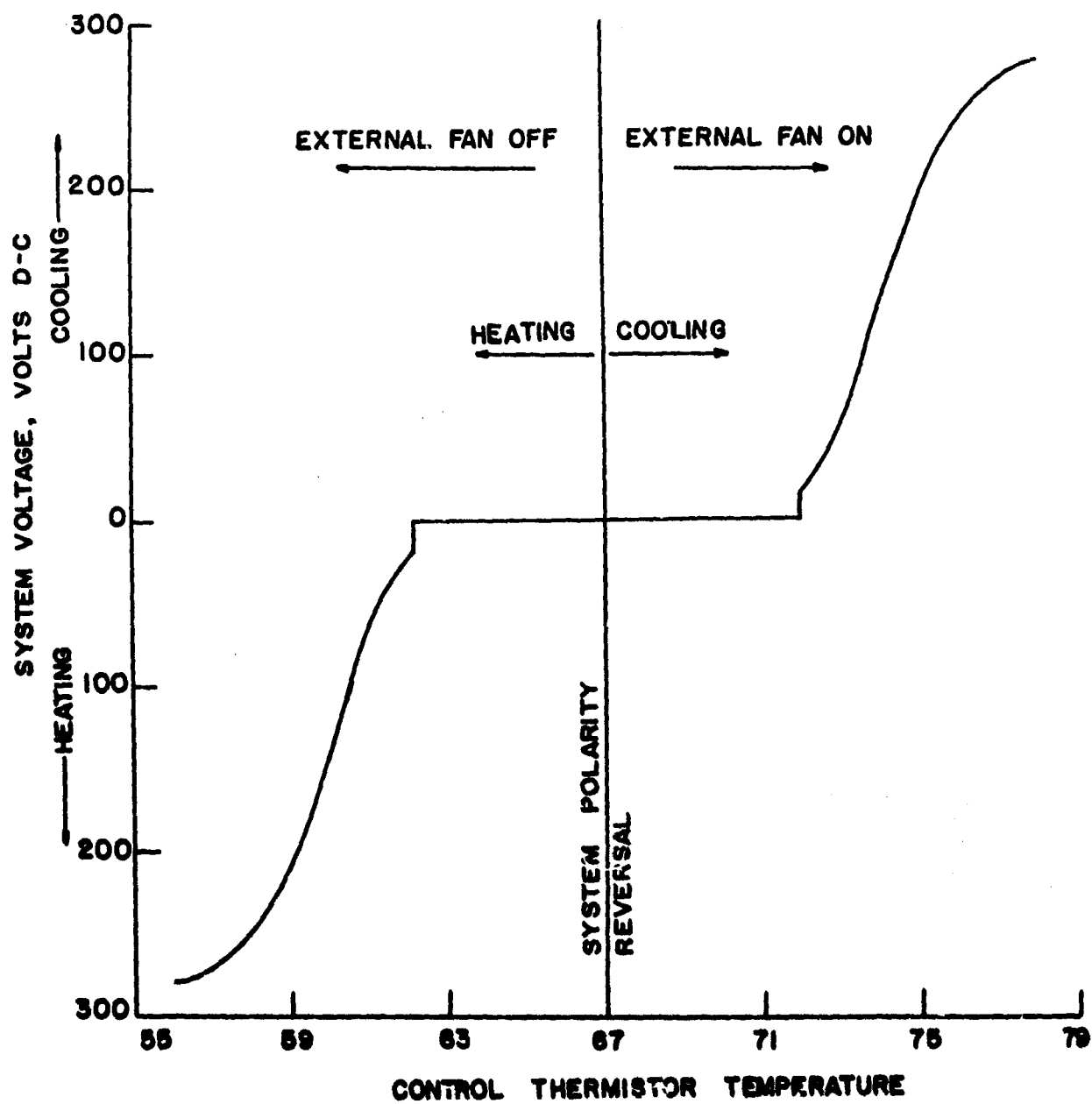


Figure 7. System Control Characteristics

4.1.2.3 Over-Temperature Protection.

In the over-temperature protection circuit, the thermistors (TH2, TH3, TH4, TH5) are located to protect the system against over-temperature conditions which could be caused by an inoperative fan or by a blocked air passage. If the temperature of any one of these thermistors exceeds 160°F during operation, then control relay (CR2) is energized, which in turn de-energizes the main contactor (MC) removing power from the thermoelectric coil. Simultaneously, the reset warning light on the control panel will go on indicating an over-temperature condition has occurred. To resume operation after an over-temperature condition occurs, the "reset" button must be depressed.

4.2 Operating Procedure

4.2.1 Automatic Operation. To operate this unit in the automatic mode, the following sequential procedure should be followed:

1. Selector switch . . . AUTO
2. External fan AUTO
3. Fan power ON
4. Main power ON

Both the main power and the fan power indicator lights should be on. The reset light should be out; however, if the reset light is on immediately after the fan power switch is turned on, then the reset button should be pushed.

If during automatic operation, or any mode of operation, the operator wants to check the module operation, the voltage drop across any of the 12 module banks may be monitored by setting the module selector switch to the proper module bank number and reading the voltage drop from the meter.

To turn the unit off when operating in the automatic mode, the sequence is:

1. Main power OFF
2. Fan power OFF

4.2.2 Manual Operation. To operate the unit in either the manual cooling or the manual heating mode:

1. Selector switch . . . MAN. COOL OR MAN. HEAT
2. External fan AUTO
3. Fan power ON
4. Main power ON

To turn off unit:

1. Main power OFF
2. Fan power OFF

4.2.3 Manual Fan Operation. In order to operate the internal fans without operating the thermoelectric coil or the external fan, the sequential operations are:

1. Selector switch MAN. HEAT
2. External fan AUTO
3. Main power OFF
4. Fan power ON

To operate both internal and external fans with the thermoelectric coil off:

1. External fan ON
2. Main power OFF
3. Fan power ON

If the inside air temperature is above 67°F and the outdoor ambient is below 67°F, it may be possible to decrease the inside temperature to 67°F and control at this temperature without operating the thermoelectric coil. This is possible by operating the internal fans and letting the external fans cycle on and off in the automatic operating mode. To accomplish this:

1. Selector switch AUTO
2. External fan AUTO
3. Main power OFF
4. Fan power ON

To turn the unit off after any manual fan operation, simply turn the fan power switch off.

4.3 Operating Performance

Electronic analog computer calculations were made to determine the performance characteristics of this system at off-design as well as at design conditions. The operating performance at design condition was described in detail in Section 3.3.2. Figure 8 shows the plotted computer solution for the system operating at design conditions on 60 cycle power. This plot shows how the element junction temperature and the internal and external air temperatures vary with coil location.

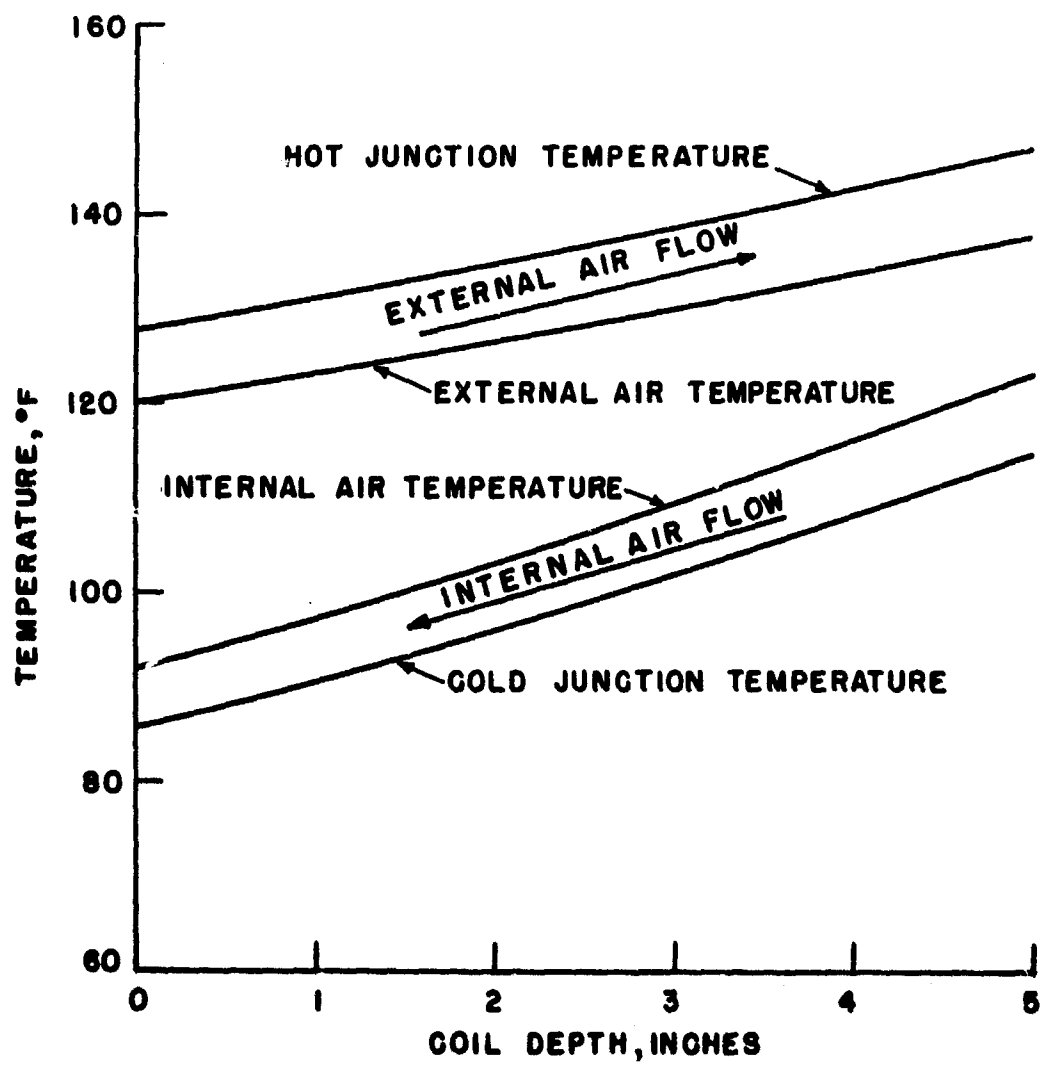


Figure 8. Thermoelectric Coil Temperature Profile at Design Operation

Off-design cooling performance was calculated for variations in outdoor ambient temperature, internal supply air temperature and operating voltage. Heating performance was calculated for variation in operating voltage. All calculations were made for both 60 and 400 cycle operation. The system power draw and COP are significantly affected by main power frequency, whereas the change in cooling capacity is insignificant. Figures 9 and 10 show how system capacity varies with ambient temperature and operating voltage for supply air temperature of 72 and 62°F, respectively. In both of these plots, the heating capacity is based on a return air temperature of 50°F. Note that zero amperage curves are shown rather than zero voltage. The reason for this is that when the SCR's are shut off, there is still a back EMF on the system generated by the thermoelectric coil. In certain cases, this generated voltage may exceed 60 volts. Figures 9 and 10 are of primary interest because they give a good representation of how the system will perform under normally expected conditions of operation. It is interesting to note that there is a large range of operation between zero amperage heating and zero amperage cooling. Within this range, the system will control the inside air temperature at the set point temperature of 67°F by simply turning the external fans off and on as required.

Figure 11 shows how system performance during cooling operation varies with outdoor ambient air temperature and operating voltage. System capacity, power draw and coefficient of performance are all shown for 60 cycle operation and a supply air temperature of 72°F.

Figure 12 shows the same performance information when the supply air temperature is 62°F, and Figures 13 and 14 show similar curves for the system operating on 400 cycle power.

Figures 15 and 16 show how system performance during full cooling operation varies with outdoor ambient air temperature and supply air temperature. Again system capacity, power draw, and coefficient of performance may be determined from the plot. Figure 15 represents 60 cycle operation and Figure 16 represents 400 cycle operation. These two plots are of greatest interest because they represent how the system will operate in the manual cooling mode. They also show the system design operating condition.

The exact procedure used to calculate the performance information is located in the calculation section of Copy No. 1 of this report. Tabulated data is also provided which shows such information as operating current, fan power requirements, etc.

60 OR 400 CYCLE POWER
 SUPPLY AIR TEMPERATURE COOLING = 72°F
 RETURN AIR TEMPERATURE HEATING = 50°F

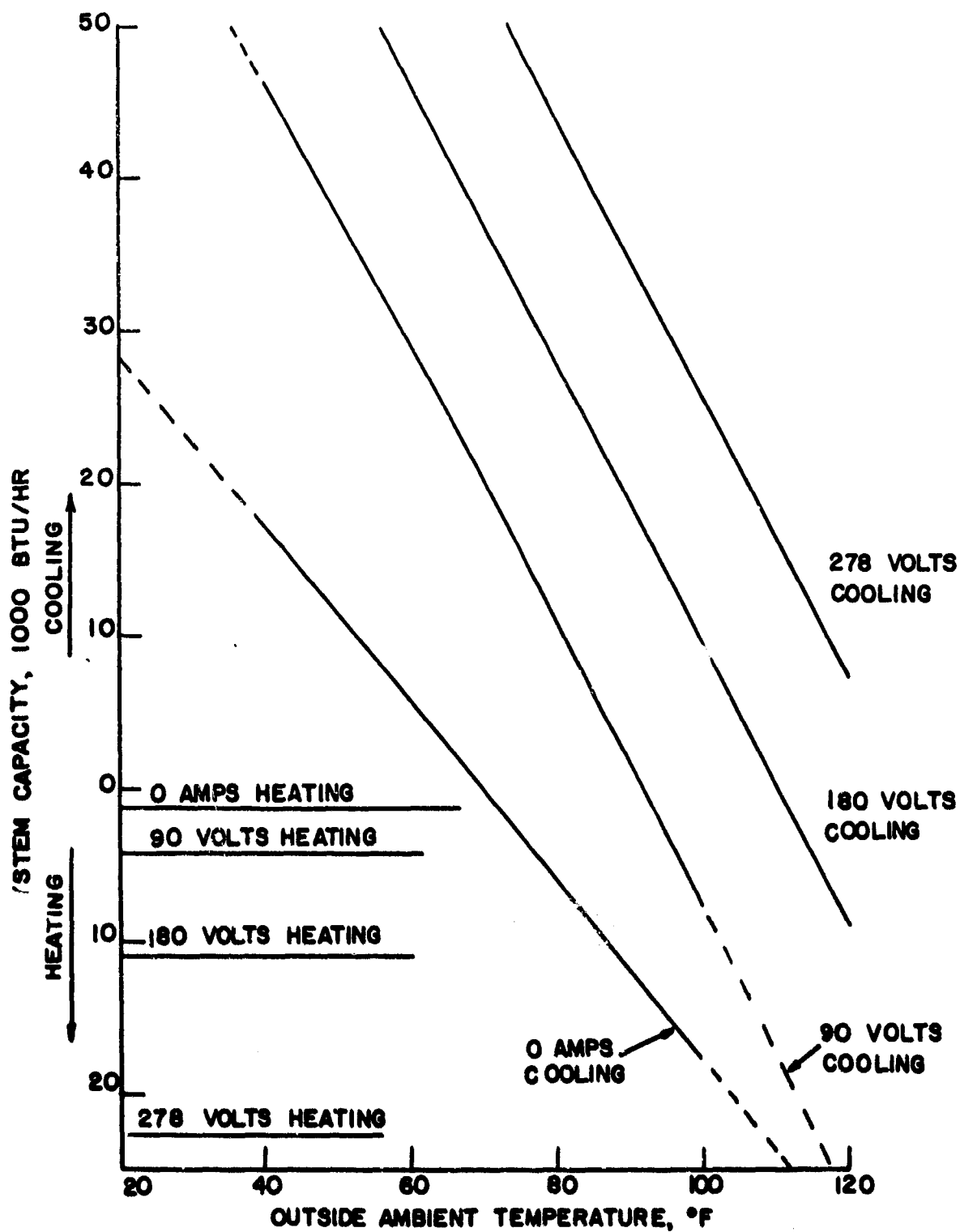


Figure 9. Operating Performance Curve Showing Capacity as a Function of Ambient Temperature and Operating Voltage

60 OR 400 CYCLE POWER
 SUPPLY AIR TEMPERATURE COOLING = 62°F
 RETURN AIR TEMPERATURE HEATING = 50°F

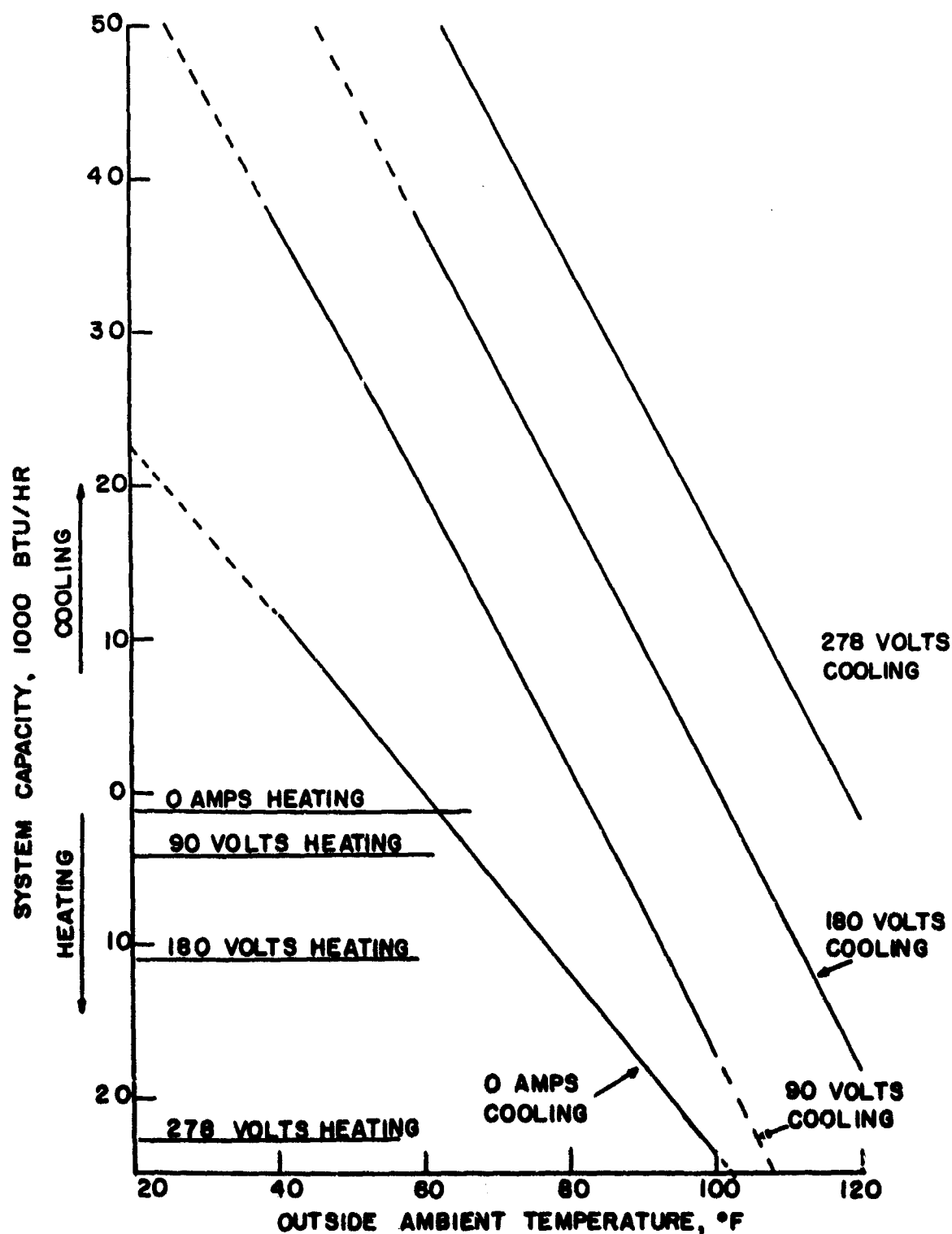


Figure 10. Operating Performance Curve Showing Capacity as a Function of Ambient Temperature and Operating Voltage

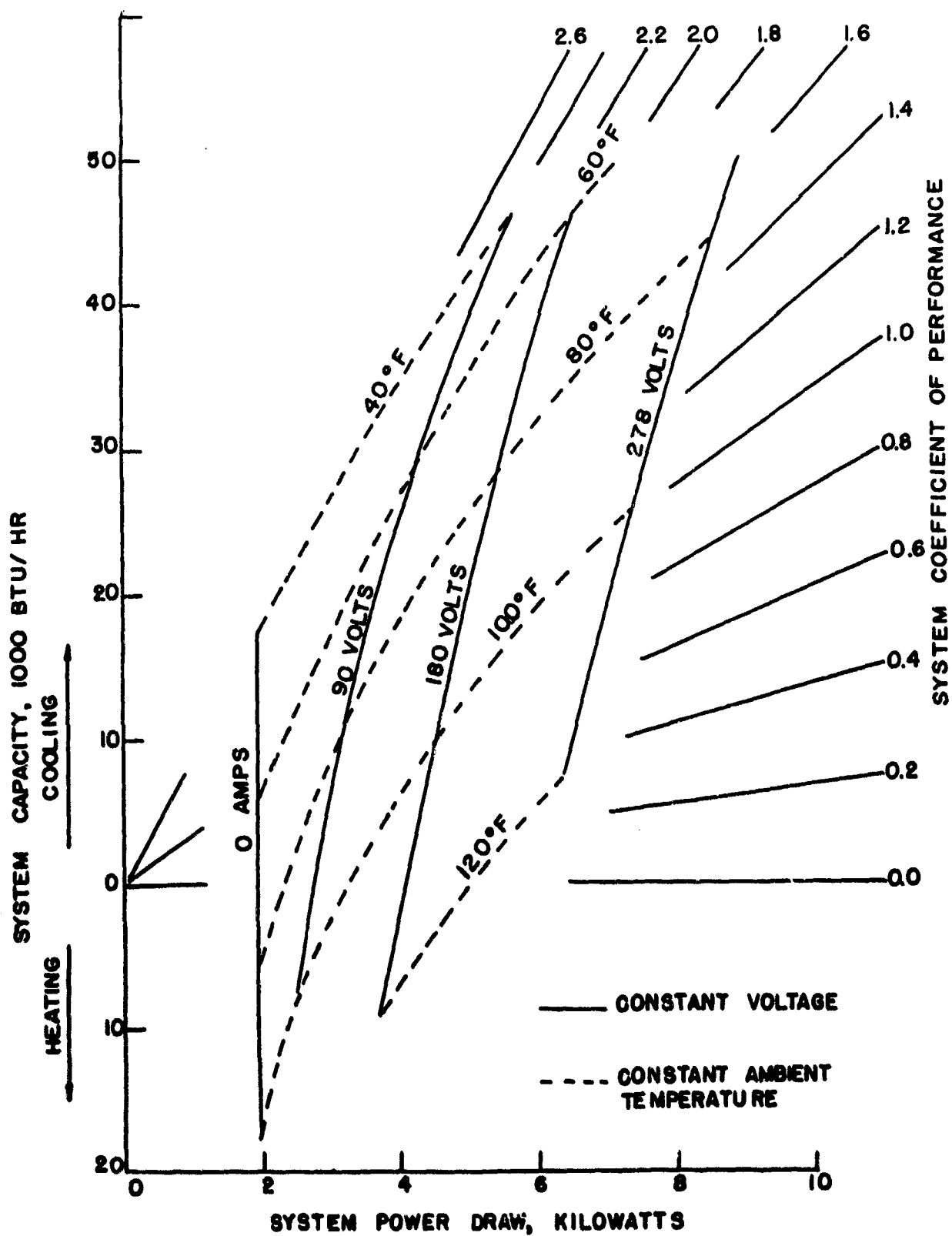


Figure 11. System Cooling Performance
(72°F Supply Air Temperature, 60 Cycle Power)

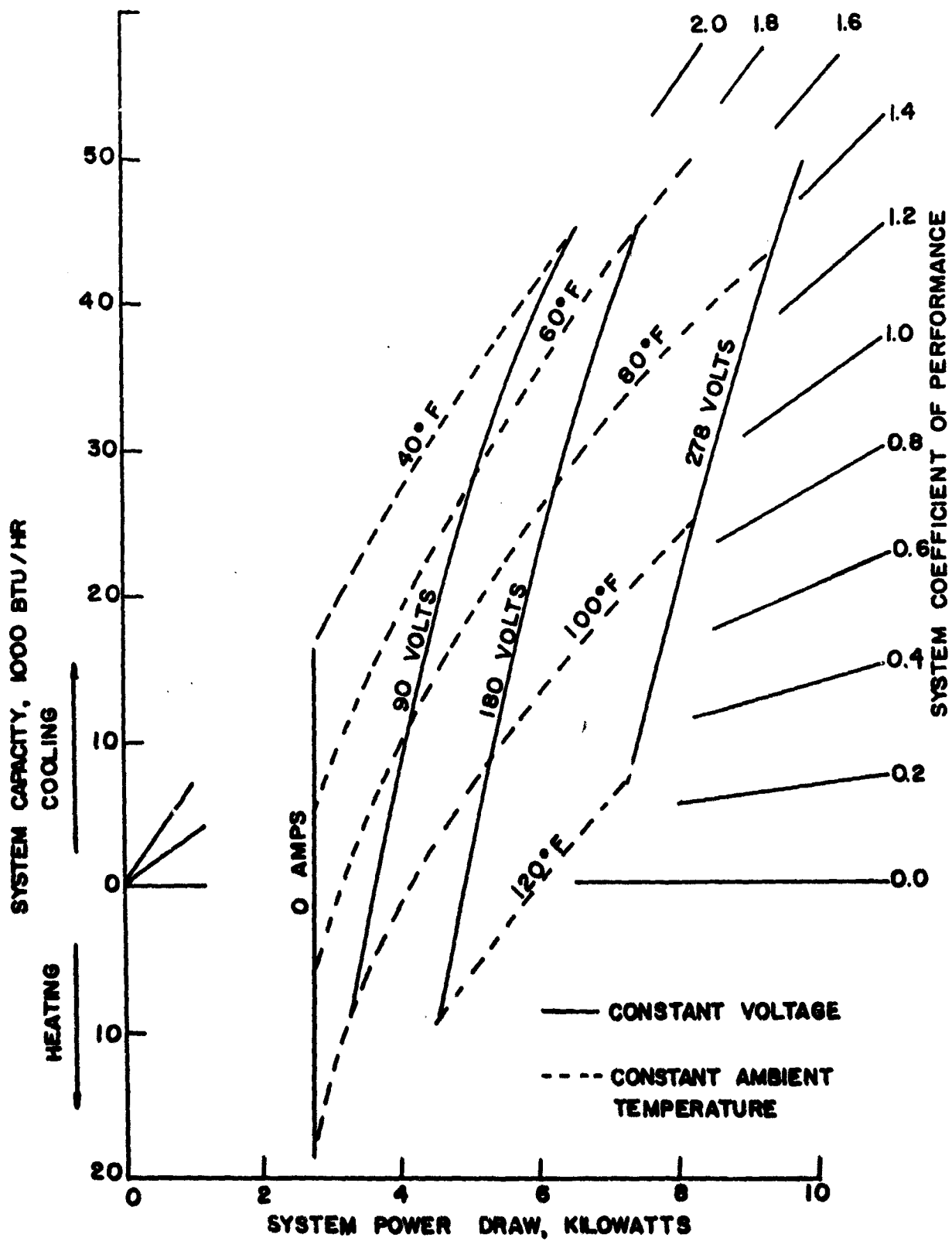


Figure 12. System Cooling Performance
(72°F Supply Air Temperature, 400 Cycle Power)

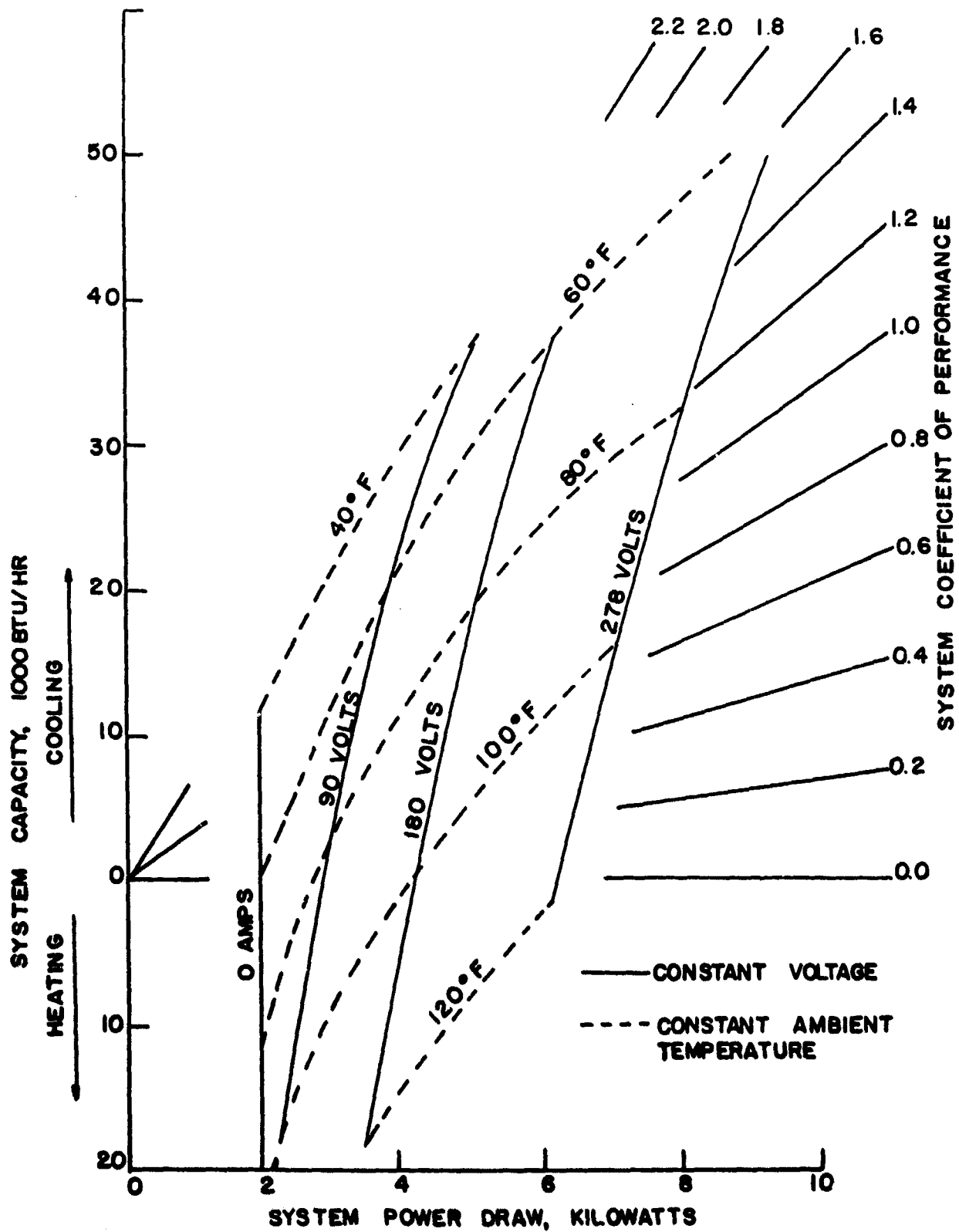


Figure 13. System Cooling Performance
(62°F Supply Air Temperature, 60 Cycle Power)

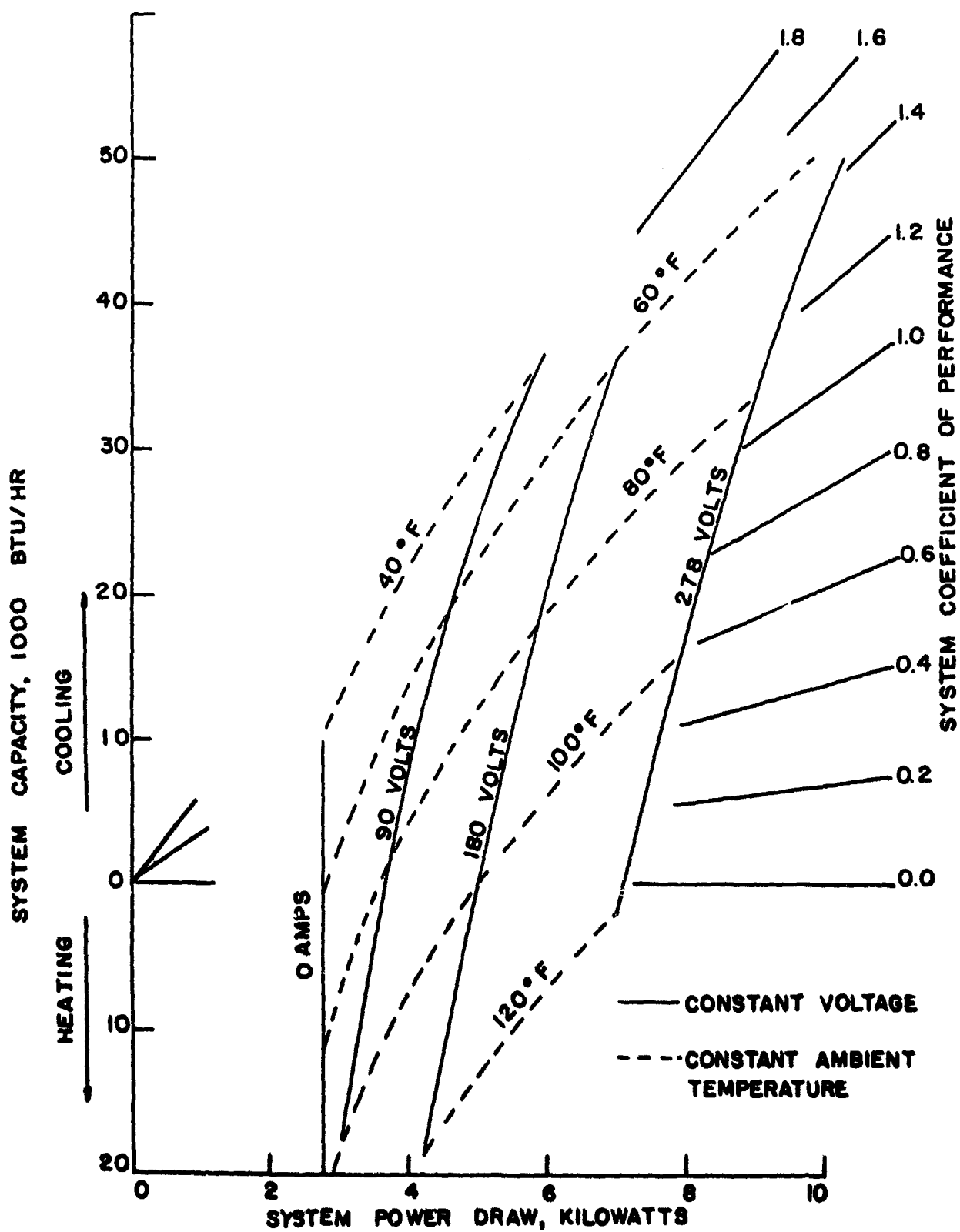


Figure 14. System Cooling Performance
(62°F Supply Air Temperature, 400 Cycle Power)

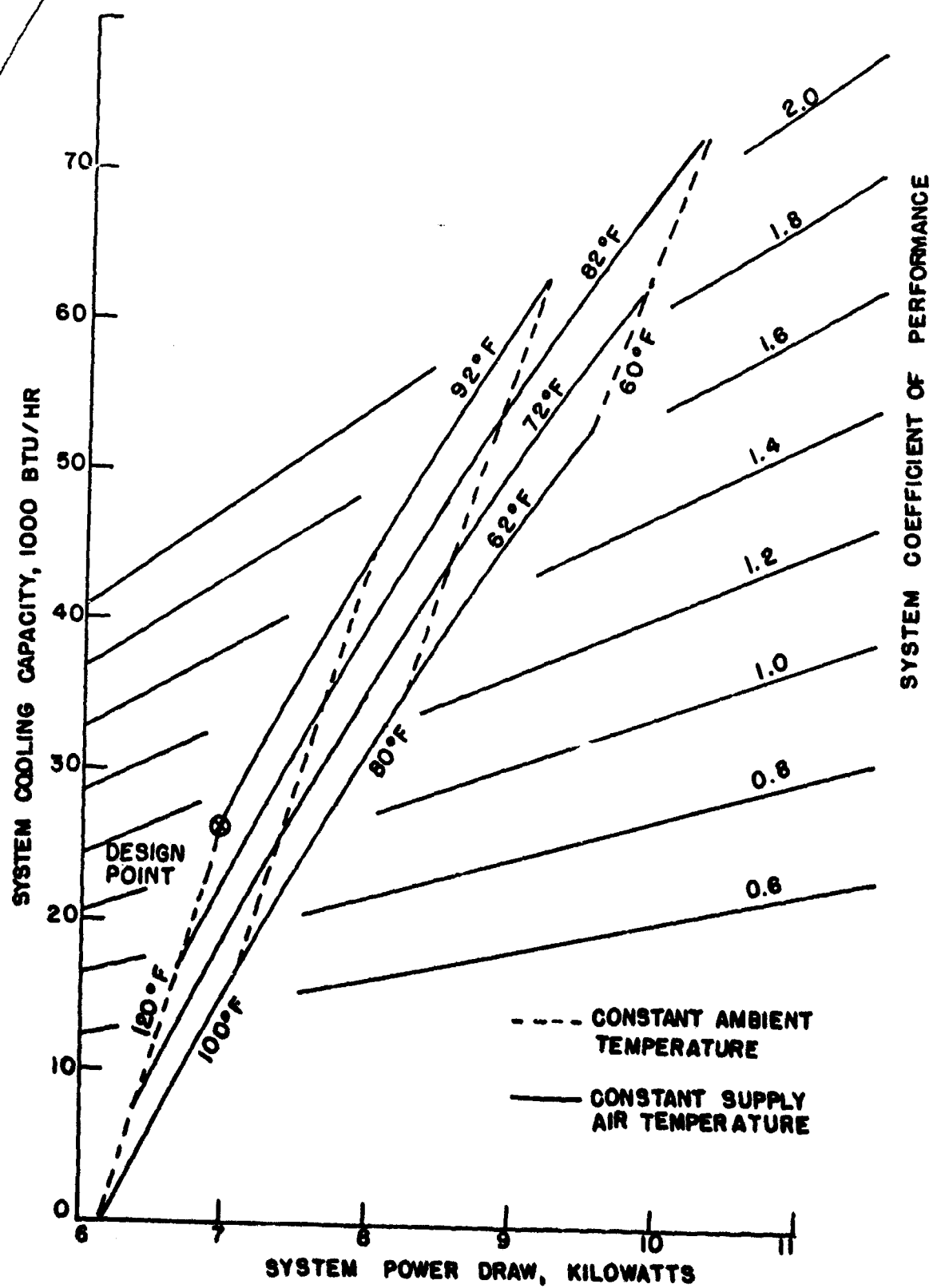


Figure 15. System Cooling Performance
(278 Volt Operation, 60 Cycle Power)

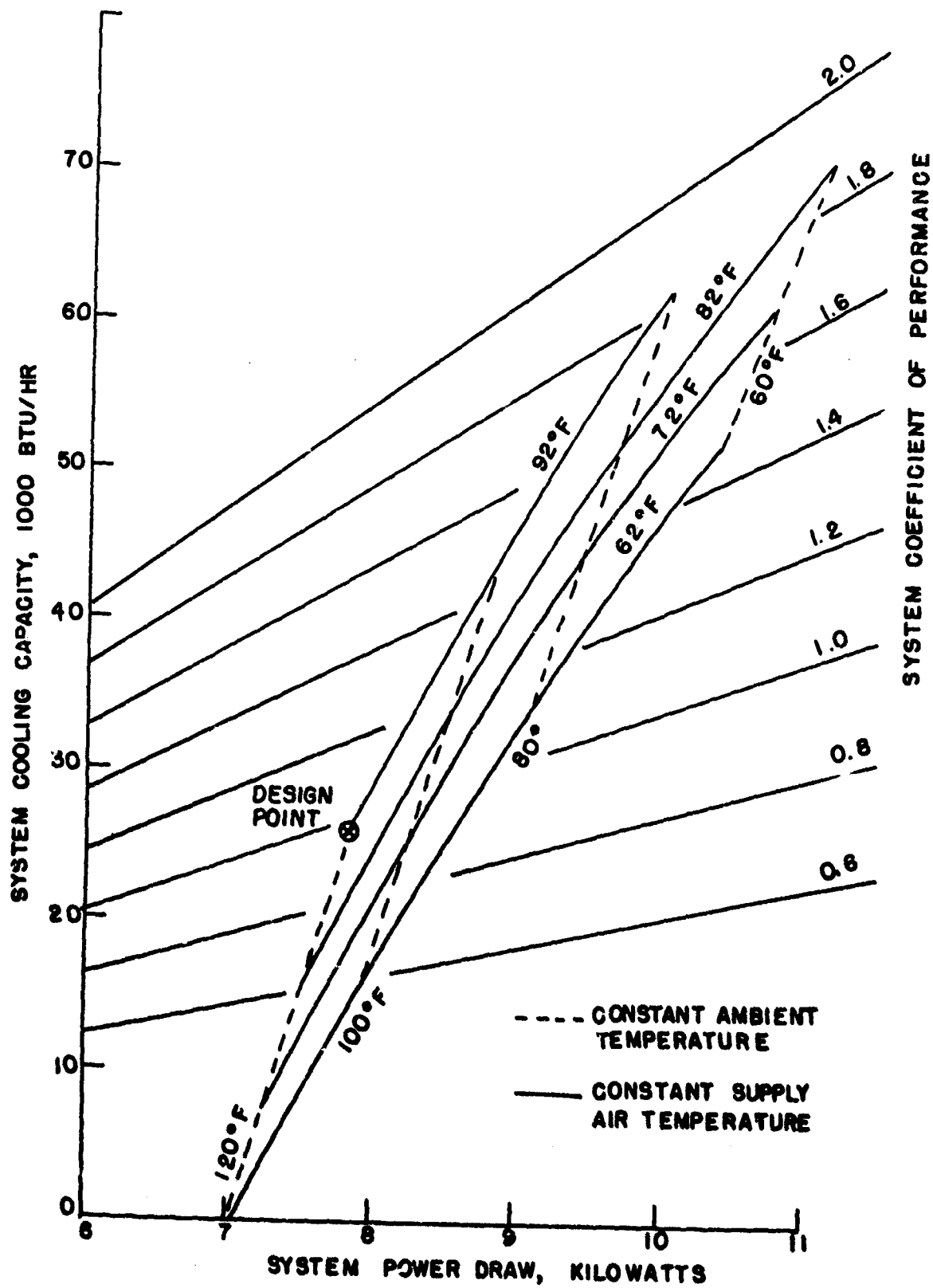


Figure 16. System Cooling Performance
(278 Volt Operation, 400 Cycle Power)

5.0 MAINTENANCE PROCEDURES

5.1 Thermoelectric Module

A thermoelectric module with a broken junction may either be replaced with a spare module or electrically removed from the circuit while it physically remains in the thermoelectric coil. To replace a thermoelectric module:

- (1) Remove access cover from outside face.
- (2) Identify the bank which contains the defective module.
- (3) Remove the top module in this bank by sliding it up about 1 inch and then out.
- (4) Remove successive modules from the bank in the same manner until the defective module has been removed.
- (5) Replace with a spare module making sure that the module connector pins are properly in place.
- (6) Replace the other modules into the bank, again insuring that all connector pins are properly in place.
- (7) Replace and fasten down the access cover.

If a spare module is not available, then a defective module may be electrically removed from the circuit by the following procedure:

- (1) Remove access cover from outside face.
- (2) Remove the top module as described perviously.
- (3) Remove successive modules from the bank in the same manner until the defective module has been removed.
- (4) After removal of the defective module, replace all other modules into the bank such that each module is one position below its original position.
- (5) Leaving the jumper strap in its original position across the top of the uppermost module, replace the bad module into the top position after removing the connector pins.
- (6) Replace and fasten down the access cover.

5.2 Internal Fan

In order to remove an internal fan:

- (1) Remove access cover from outside face.
- (2) Remove the internal air baffle from the front of the fans.
- (3) Disconnect fan electrical connector.
- (4) Remove fan mounting bolts and remove fan.
- (5) Replace fan by reversing steps 1, 2, 3, and 4.

5.3 External Fan

To remove an external fan:

- (1) Remove access cover from outside face.
- (2) Disconnect fan electrical connector.
- (3) Remove fan mounting bolts and remove fan.
- (4) Replace fan by reversing steps 1, 2, and 3.

5.4 Control and Power Conversion Package

To remove the control and power conversion package:

- (1) Remove access cover from outside face.
- (2) Remove one external fan.
- (3) Remove all electrical connectors from control box.
- (4) Remove screws fastening the control box to the unit frame and remove control box.
- (5) Replace box by reversing steps 1, 2, 3, and 4.

To remove a printed circuit card from the control and power conversion package:

- (1) Remove cover from package.
- (2) Slip card from connector and replace with a spare card.
- (3) Replace cover.

To remove a bad diode or SCR from the rectifier bridge:

- (1) Remove cover from the control box.
- (2) Disconnect lead wires from the defective diode or SCR.
- (3) Remove the defective component and replace with a spare.
Care should be exercised to prevent stripping the copper threads. If a torque wrench is available, the components should be torqued to 30 in. -lb.
- (4) Replace the lead wires.
- (5) Replace cover.

5.5 Frequency Changeover

The fan motors and the firing circuit for this system are frequency sensitive. Consequently, they must be wired for the proper supply frequency. On the firing circuit, a jumper wire must be removed when the unit is operated at 400 cycles. This wire is marked as indicated on the schematic wiring diagram. Conversely, when operating on 60 cycle this wire must be connected in position.

The fan motors are dual frequency with a separate set of lead wires for each frequency. Each set of wires is connected to an MS connector. The connectors are clearly marked 60 cycle or 400 cycle. The proper connection is determined by the main power supply frequency.

6.0 MANUFACTURING PROCEDURE

The manufacturing procedure used to process thermoelectric panels consists principally of processing semiconductor elements and insulated conductor straps and assembling them into the panel circuit. Detailed process sheets are available which describe the exact step-by-step procedures that have been developed at Carrier's thermoelectric process development and pilot production facility. The applicable process sheets are included in Appendix B.

7.0 COST ESTIMATE

The Purchase Description requests a cost estimate for fabricating one prototype unit and total costs for producing quantities of 10, 50 and 600 units per buy. A detailed price analysis is presented in Figure 17 to show prototype development costs and an estimate for producing ten units. An explanation is in order for these cost estimates as well as for the larger production quantities.

Input data for the price analysis shown has been obtained from actual experience using existing thermoelectric process development facilities and the manufacturing methods described in the previous section. Existing facilities and procedures are adequate for prototype development and for a limited production to meet the requirements of field trial qualification. After absorption of non-recurring development costs, there would be only minor differences in cost per unit up to the maximum capability of the existing facilities and using the manufacturing procedures described earlier. In other words, after the first unit is developed, whether the additional requirement is for three units, five or ten, only slight cost improvement would be possible. The maximum capability of the facility now in use would be about ten units, considering a reasonable delivery time for fabrication. Therefore, the information presented in the price analysis for producing one and ten units should be regarded as reasonably representative for any number within this range, the major difference for quantities smaller than ten being in material costs. Likewise, to reflect substantial reductions in cost, a scale-up to meet volume production requirements would be necessary. This, of course, is not reflected in the price for a range from one to ten units.

For quantities of 50 and 600 units per buy, increased automation of routine procedures would be employed. High volume operations would justify capital expenditures to reduce labor costs and to improve process yield, both of which are significant percentages of unit cost in small quantities as produced by existing methods. One of the major advantages of producing a small number of units, say three to ten, would be to establish production measures which could be employed for large scale-up in capacity.

It is fully recognized that cost will play a major role in determining the ultimate feasibility of thermoelectric systems. The advantages of reliability, size, weight and performance characteristics will, in the final analysis, have to be related to cost in comparison with a conventional system. Carrier believes that the effect of a scale-up to meet true production requirements will be of major significance in reducing thermoelectric system cost to a level where it is competitive with more conventional systems. We do not

CARRIER AIR CONDITIONING COMPANY

MILITARY EQUIPMENT DEPARTMENT
PRICE ANALYSIS

Purchaser USAERDL, Fort Belvoir, Va. Contract No. DA-44-009-AMC-1135(T)
Project Thermoelectric Environmental Control Unit Date September, 1965
Applicable Spec. RFQ No. 65-1816B Estimated by _____
Type Units Thermoelectric Checked by _____

PRICE ITEMIZATION	Non-Recurring Preproduction Costs (No. Units <u>0</u>)	Production Costs (No. Units <u>1</u>)	Production Costs (No. Units <u>10</u>)
DIRECT MATERIAL			
Raw Material -----		5,800	47,000
Purchased Parts -----		4,700	35,100
FACTORY LABOR			
<u>1,900</u> Hrs at \$ <u>3.95</u> /Hr -----		7,505	
<u>14,500</u> Hrs at \$ <u>2.50</u> /Hr -----			36,250
FACTORY OVERHEAD <u>145</u> % -----		10,882	52,563
ENGINEERING LABOR			
<u>2,000</u> Hrs at \$ <u>6.50</u> /Hr -----	13,000		
<u>500</u> Hrs at \$ <u>5.25</u> /Hr -----		2,625	5,250
ENGINEERING OVERHEAD <u>85</u> % -----	11,050	2,231	4,463
DRAFTING LABOR			
<u>500</u> Hrs at \$ <u>4.25</u> /Hr -----	2,125		
DRAFTING OVERHEAD <u>85</u> % -----	1,806		
OTHER DIRECT COSTS			
1. TESTING MATERIALS - COSTS			
(a) Testing Labor: 100 hrs at 3.95 x 2.45 -----		968	
(c) Testing Labor: 400 hrs at 2.50 x 2.45 -----			2,450
TOTAL MANUFACTURING COSTS -----	27,981	34,711	183,076
GENERAL & ADMINISTRATIVE EXPENSE <u>15</u> % -----	4,197	5,207	27,461
TOTAL COST -----	32,178	39,918	210,537
PROFIT <u>10</u> % -----	3,218	3,992	21,054
MISCELLANEOUS COSTS			
(a) -----			
(b) -----			
(c) -----			
TOTAL SELLING PRICE (No. of Units _____) -----	35,196	43,910	231,591

Figure 17. Detailed Price Analysis

believe, however, that it is possible, without the experience of prototype development and a limited production for field evaluation purposes, to predict an accurate unit cost for large volume requirements.

It is our belief that no one is in a better position to predict the cost of developing and producing a system of the type described than Carrier. We are the only company to date that has developed and produced a thermoelectric air conditioning system for a commercial application, namely the 28 units provided for the S.C. Johnson application described previously. On the basis of this experience, we believe that a projection of costs to large production quantities would be misleading until after the important first steps of prototype development and limited production for field trial qualification have been completed successfully.

8.0 SUMMARY OF RESULTS

A system analysis has been completed for a 24,000 Btu/hr thermoelectric environmental control unit. In this analysis an electronic analog computer was used to optimize 12 system parameters for minimum weight and maximum efficiency. All important sub-systems and sub-system components were also analyzed by weighing the advantages and disadvantages of the design possibilities considered.

From this analysis a design was formulated to meet the system requirements as described in the Purchase Description. A complete set of assembly drawings are provided. The resulting thermoelectric environmental control unit has outside dimensions of 28 inches wide by 18 inches deep by 63 inches high, weighs 380 pounds and will provide 24,000 Btu/hr cooling capacity at an overall system coefficient of performance of 1.12.

Calculations were made to determine the off-design performance characteristics of this system. Performance information is presented in graphical form, and a complete description of how the system operates is included. Operating instructions, maintenance procedures, manufacturing procedures and cost analysis information are also presented.

9.0 RECOMMENDATIONS

On the basis of the results presented herein, it is recommended that development of a prototype unit be initiated. The objectives outlined in the Purchase Description have been met or exceeded by the design provided. Carrier is confident that a successful prototype unit can be built which will be in complete accord with all of the physical and performance characteristics of the design shown.

It is estimated that delivery of a completed unit can be made within nine months from the date of contract award. As shown in the price analysis included in Section 7.0, the estimated cost for producing one unit of the type designed is:

None-recurring developmental costs	\$35,196
Production cost	<u>43,910</u>
Total estimated cost	\$79,106

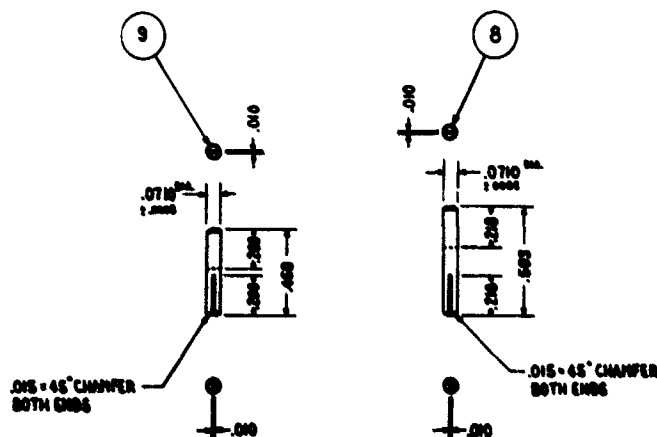
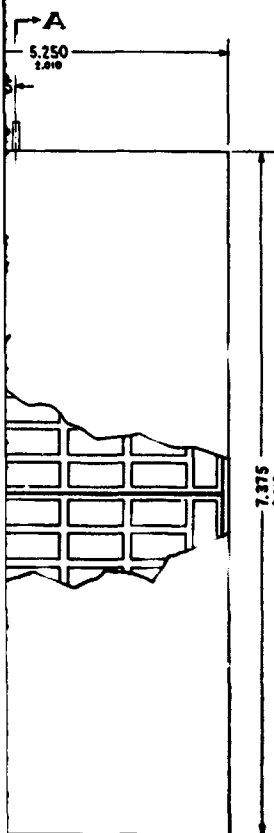
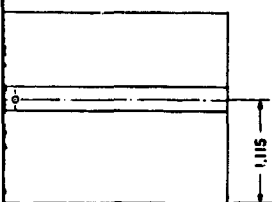
We will welcome the opportunity of working with USAERDL in developing this unit and believe that it is an important and worthwhile step in the application of thermoelectricity to military requirements.

APPENDIX A

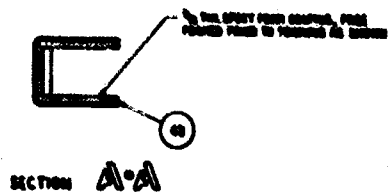
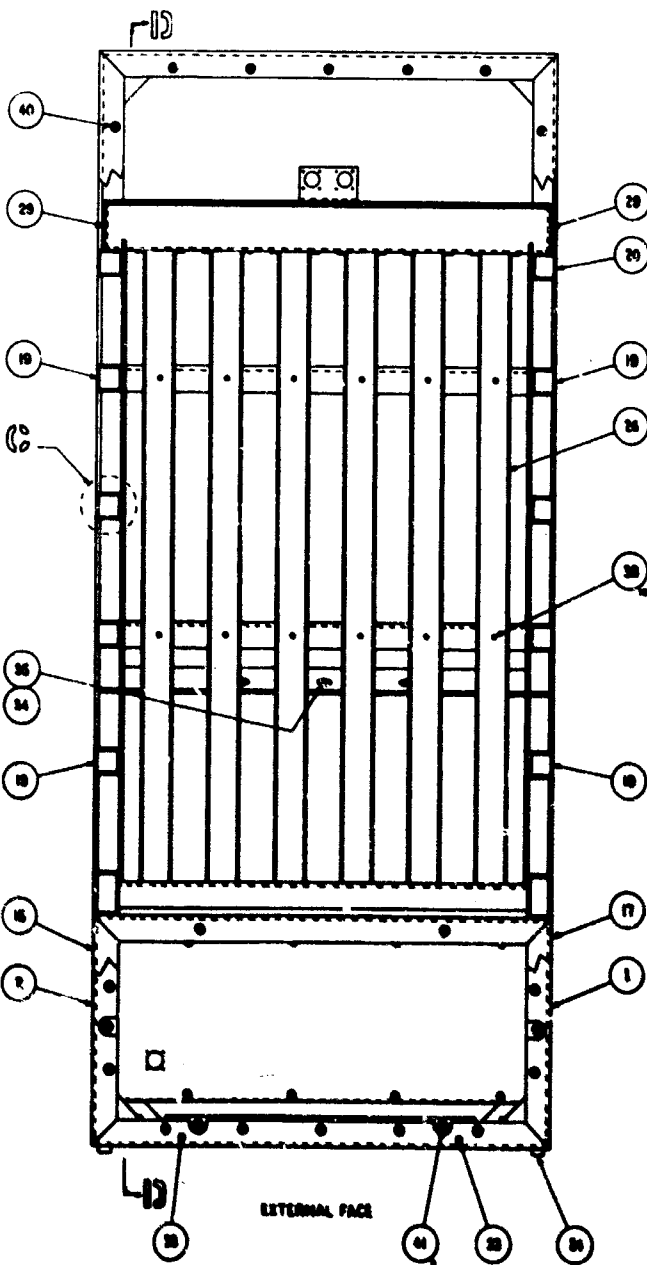
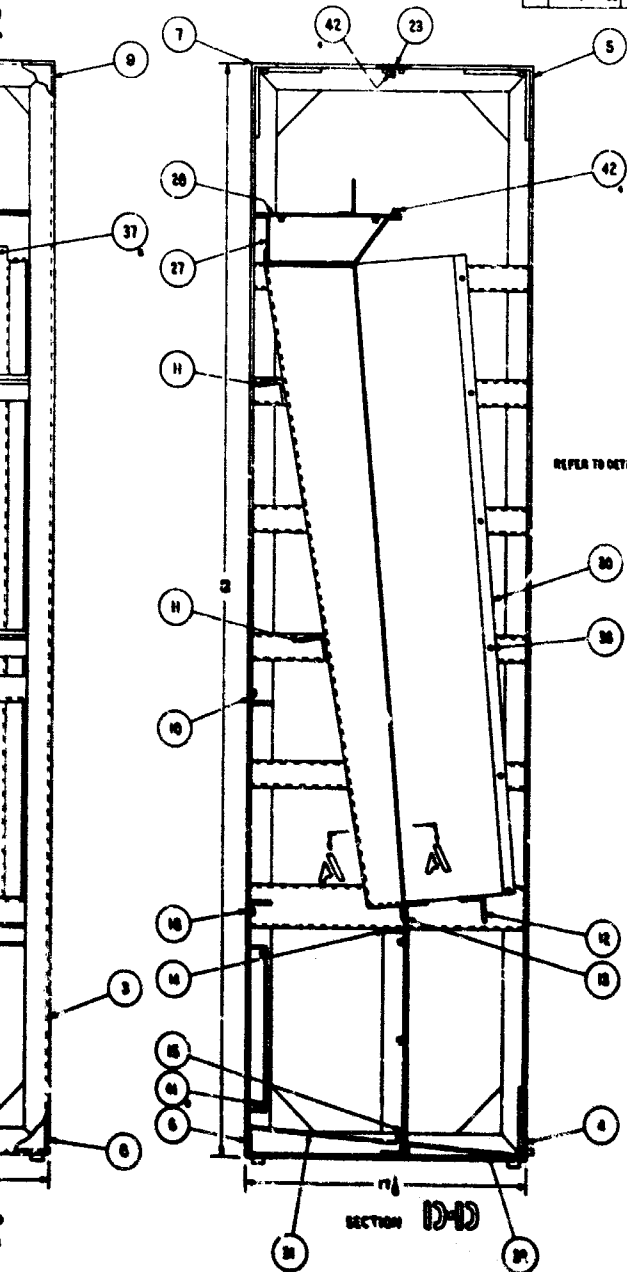
LIST OF ASSEMBLY AND SCHEMATIC DRAWINGS

1. R1058-3429 Panel Assy. for T. E. Environmental Control Unit
2. R1058-4430 Module Assy. for T. E. Environmental Control Unit
3. R1058-9434 Frame Assembly for T. E. Environmental Control Unit
4. R1058-9431 Control and Monitor Panel for T. E. Environmental Control Unit
5. R1058-3432 Temperature Sensor Assembly for T. E. Environmental Control Unit
6. R1058-9433 Power Conversion & Control Package for T. E. Environmental Control Unit
7. R1058-4435 Access Cover Assembly for T. E. Environmental Control Unit
8. R1058-9436 Unit Assembly for T. E. Environmental Control Unit
9. R1058-3437 Module Receptacle for T. E. Environmental Control Unit
10. R1058-9439 Air Flow Diagram for T. E. Environmental Control Unit
11. R1058-4428 Schematic Diagram Control and Power Supply for T. E. Environmental Control Unit

ITEM	DWG./PART NO.	REQD.	DESCRIPTION (FINISHED SIZE)	MATERIAL	
1	RI05B-3429	4	PANEL ASSY.		
2	RI05B-4430-2	2	.006 THK. x .500 HIGH x 5.250 x 7.875 LG. FINNED STOCK 30 FINS/INCH STRAIGHT PATTERN		
3		-3	2	.006 THK. x .400 HIGH x 5.250 x 7.375 LG. FINNED STOCK 30 FINS/INCH STRAIGHT PATTERN	
4		-4	2	.020 THK. x 5½ x 7⅞ LG.	ALUMINUM
5		-5	2	.010 THK. x 5½ x 7⅞ LG.	
6		-6	1	.010 THK. x 5½ x 8⅞ LG.	
7		-7	1	.010 THK. x 5½ x 8⅞ LG.	
8		-8	2	⅜ DIA. x 19/32 LG.	FREE CUTTING BRASS
9		-9	2	⅜ DIA. x 19/32 LG.	

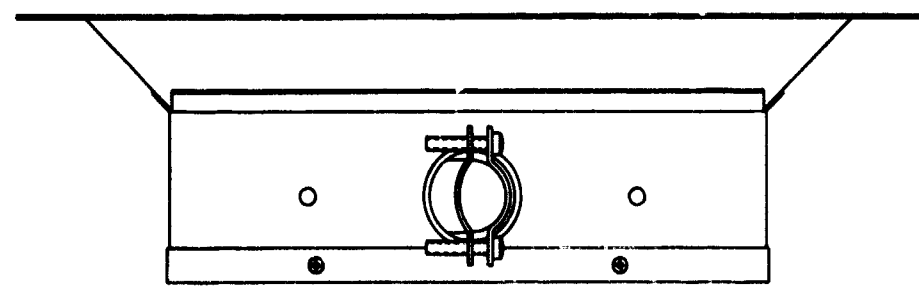
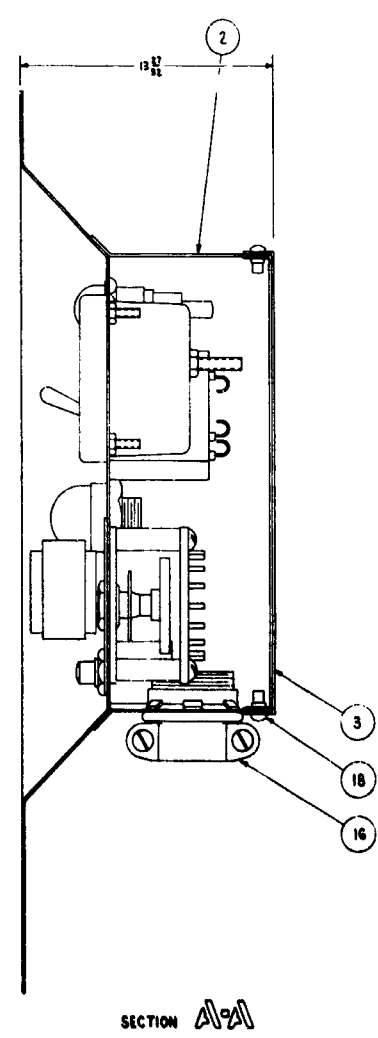
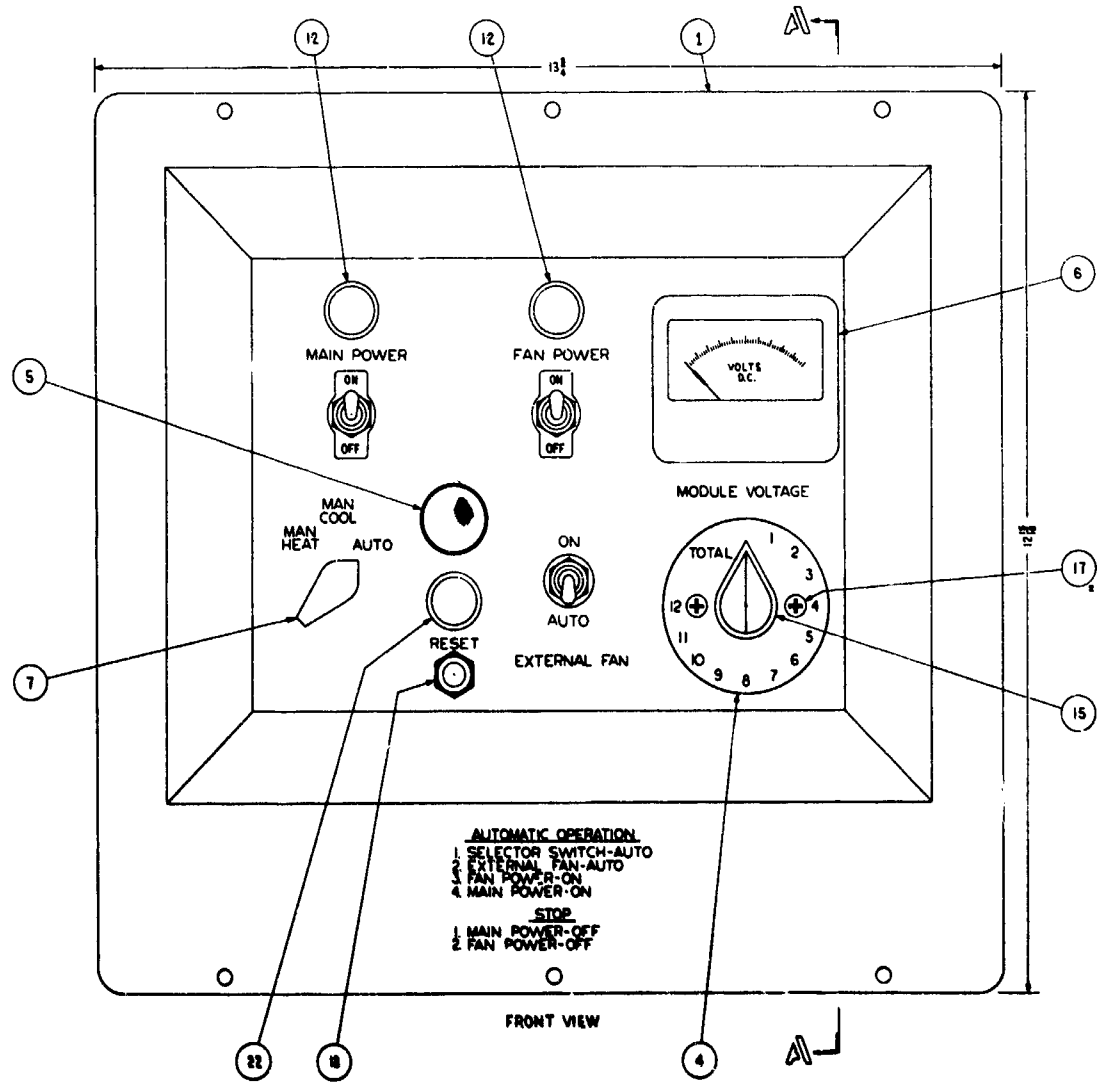
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33	R1058-9434-23	2	TUBE - O.D. .035 WALL - 1/2 LG.	ALUMINUM 6061-T6	17	R1058-9434-17	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	ALUMINUM 6061-T6	1	R1058-9434-1	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	ALUMINUM 6061-T6
34	MS20426-AN2-6	12	RIVET - 1/4 DIA. - 1/4 LG. COUNTERSUNK HD.	ALUMINUM 1900-2	18	-18	1	ANGLE - 1/2 x 1/2 x 1/2 LG.		2	-2	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
35	1321IE8385	6	RECEPTACLE - CAMLOC "12R1-1A"	PURCHASE	19	-19	4	SQUARE TUBE - 1/2 x 1/2 WALL - 1/2 LG.	ALUMINUM 6061-T6	3	-3	2	ANGLE - 1/2 x 1/2 x 1/2 LG.	
36	MS20600-BAW2	12	RIVET, BLIND, SELF PLUGGING - 1/4 DIA.		20	-20	8	SQUARE TUBE - 1/2 x 1/2 WALL - 1/2 LG.		4	-4	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
37	MS20600-BAW2	32	RIVET, BLIND, SELF PLUGGING - 1/4 DIA.		21	-21	12	GUSSET - .190 THK. - 2 x 2 (MAKES TWO PIECES)	ALUMINUM 6061-T6	5	-5	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
38	MS20600-BAW4	18	RIVET, BLIND, SELF PLUGGING - 1/4 DIA.		22	-22	12	GUSSET - .190 THK. - 4 x 4 (MAKES TWO PIECES)		6	-6	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
39	MS27131-39	8	NUT, BLIND RIVET, FLAT HD. CLOSED END - .0000		23	-23	1	TEE - 2 x 2 x 1/2 THK. - 27 LG.		7	-7	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
40	MS27131-27	30	NUT, BLIND RIVET, FLAT HD. CLOSED END - .02 UNF		24	-24	4	BAR - 1/2 DIA. - 1 LG.	ALUMINUM 6061-T6	8	-8	2	ANGLE - 1/2 x 1/2 x 1/2 LG.	
41	MS27131-21	28	NUT, BLIND RIVET, FLAT HD. OPEN END - .02 UNF		25	-25	2	125 THK. - 5 x 1/2 LG.	ALUMINUM 6061-T6	9	-9	2	ANGLE - 1/2 x 1/2 x 1/2 LG.	
42	MS27131-9	32	NUT, BLIND RIVET, FLAT HD. CLOSED END - .02 UNF		26	-26	6	.063 THK. - 6 x 40 LG. (REFER TO SECTION A-A)	ALUMINUM 6061-T6	10	-10	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
43	R1058-9434-43	12	1/2 THK. - 1/2 x 36 LG.	* FORMER HAS BEEN RE-ENGINEERED BY S&S	27	-27	1	.063 THK. - 1/2 x 27 LG.		11	-11	2	ANGLE - 1/2 x 1/2 x 1/2 LG.	
44	-44	12	1/2 THK. - 1/2 x 36 LG.	ALUMINUM 6061-T6	28	-28	1	.063 THK. - 6 x 27 LG.		12	-12	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
45	-45	1	.063 THK. - 2 x 3 LG.		29	-29	2	.063 THK. - 5 x 11 LG.		13	-13	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
46	-46	1	.063 THK. - 1/2 x 27 LG.		30	-30	8	.015 THK. - 8 x 36 LG.	STAINLESS STEEL 304	14	-14	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
					31	-31	1	.032 THK. - 8 x 30 LG.	ALUMINUM 6061-T6	15	-15	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	
					32	-32	1	.032 THK. - 7 x 28 LG.		16	-16	1	ANGLE - 1/2 x 1/2 x 1/2 LG.	

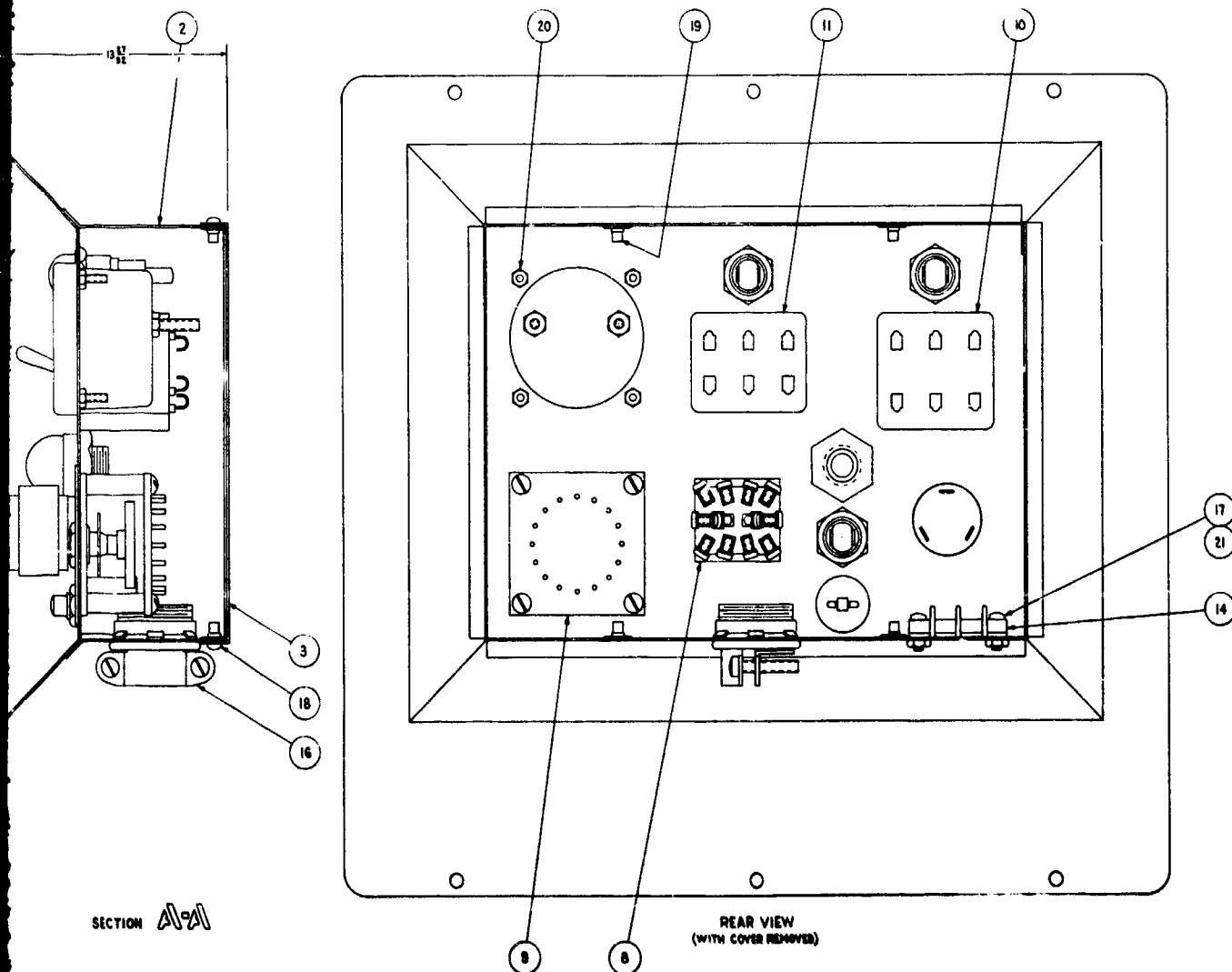


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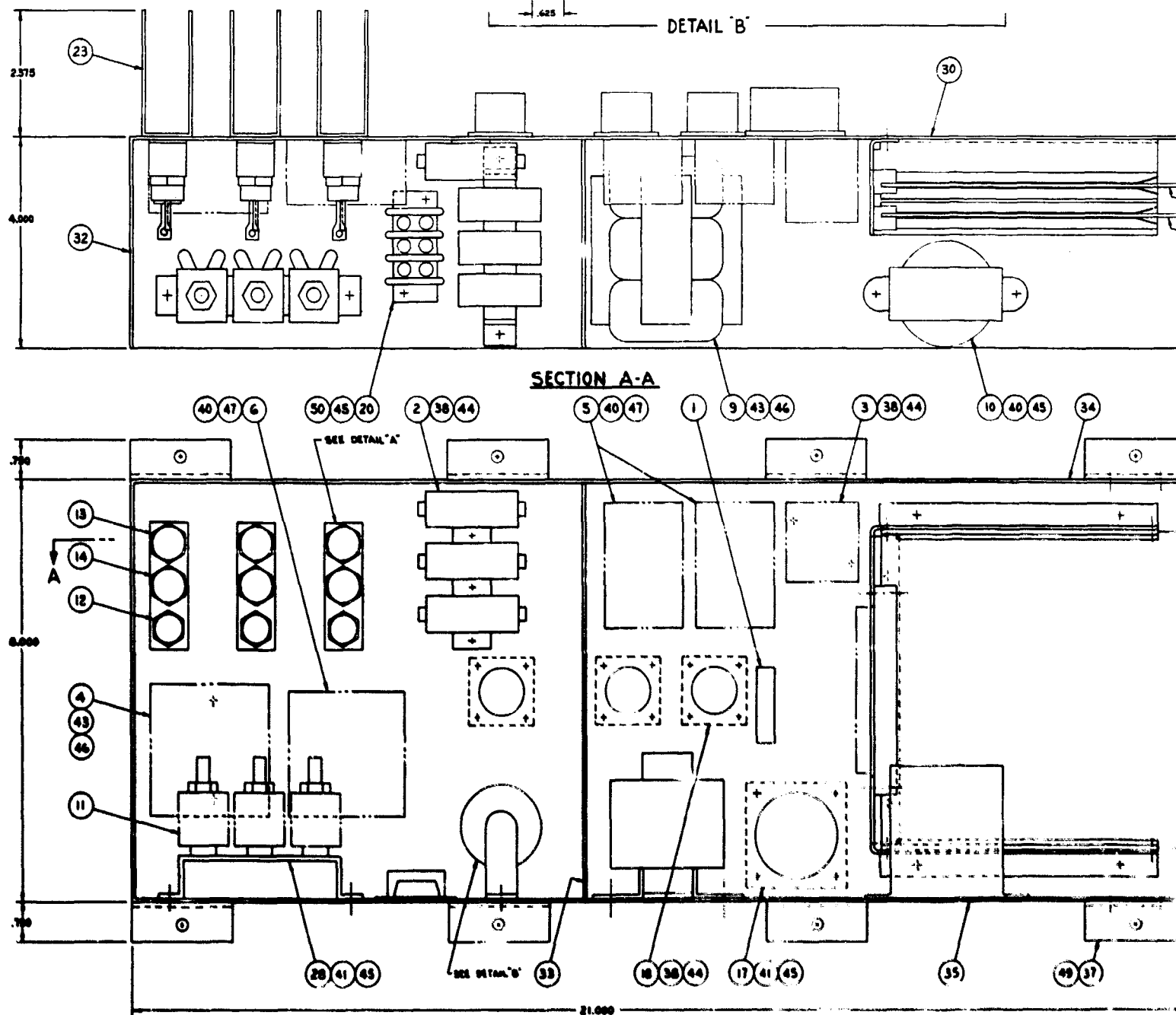
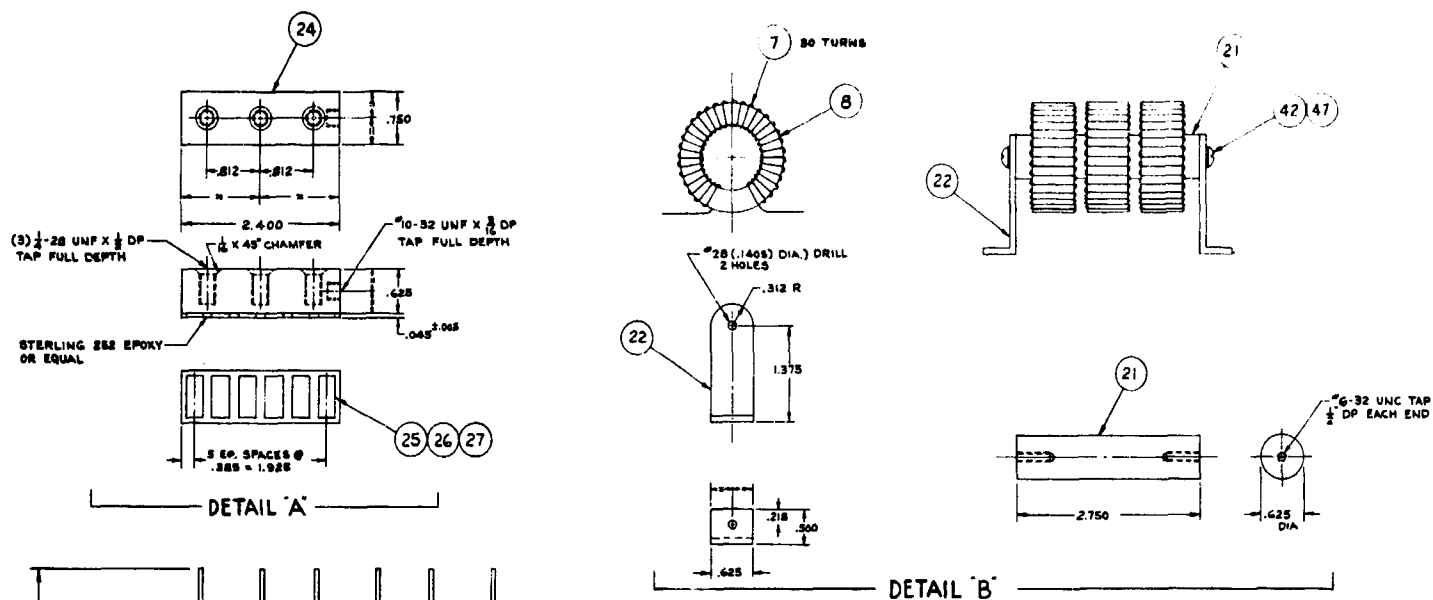
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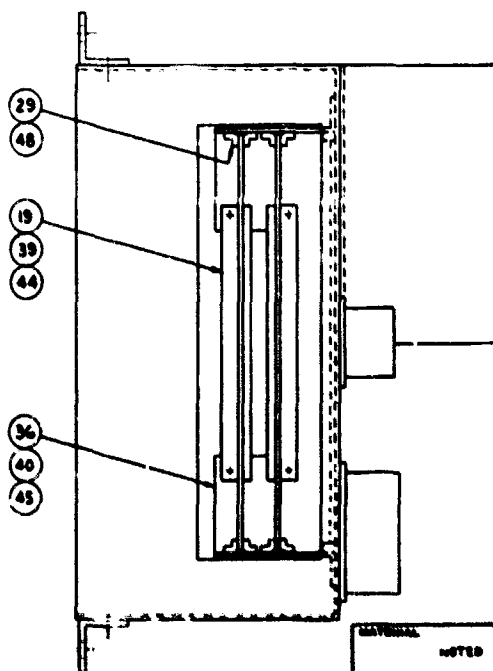
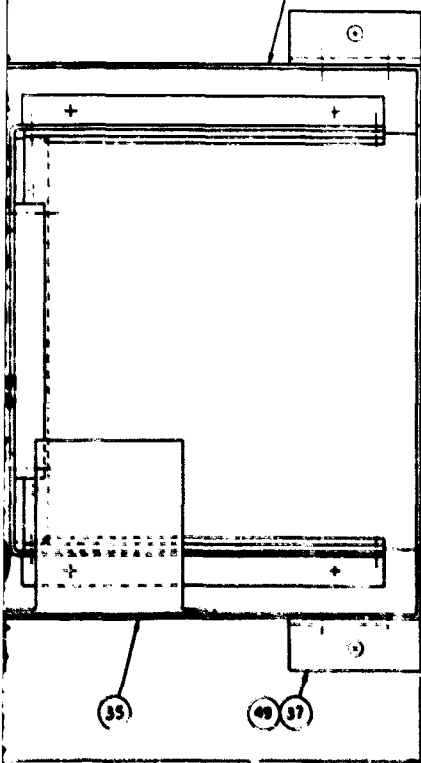
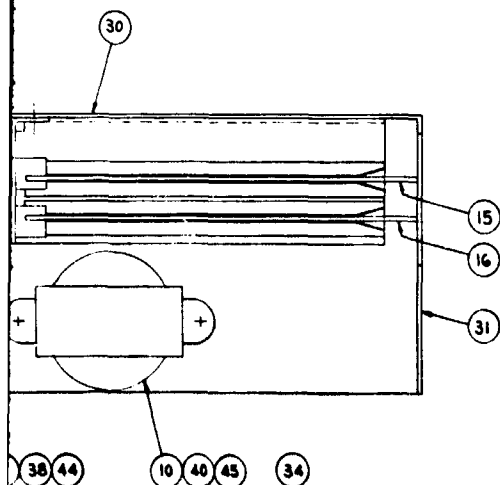
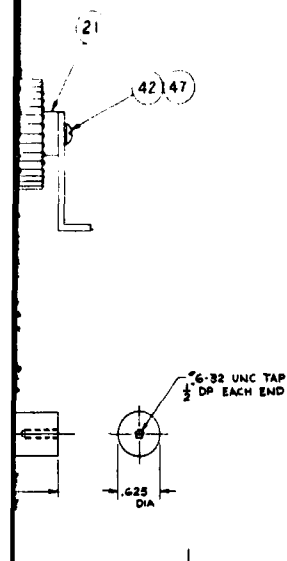


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4	1	R1058-9431-1	CONNECTOR THUMB NUTS			1	1	R1058-9431-1	PANEL - 063 THK - 12 1/2 x 18 1/2	ALUMINUM 6061-T6	
17	1	M53274-42	3/16 x 1/2 LOCK WASH SCREW			2	1		CLOSURE - 063 THK - 12 1/2 x 18 1/2		
18	1	M53274-42	3/16 x 1/2 LOCK WASH SCREW			3	1		COVER - 063 THK - 12 1/2 x 18 1/2		
19	1	M52740-1	40NC NUT, BLIND RIVET, PLAT NR			4	1		NAME PLATE - 063 THK - 12 1/2 x 18 1/2		
20	1	M52744-N04	40NC HEX LOCKNUT			5	1	R1058-9432	TEMPERATURE SENSOR ASSY.		
21	1	M52744-N04	40NC HEX LOCKNUT			6	1	R1058-9431-6	VOLT METER - WESTON - 100V, PLASTIC FRONT	PURCHASE	
22	1	M52526-6	1/8 32NC HEX LOCKNUT			7	1	SW1	3 POSITION SWITCH - CARLING - 700-12-2-BL		
			LIGHT - 14VOLT LAM - T-12			8	1	SW2	4 POLE SWITCH - J-B-T		
						9	1	SW3	ROTARY SWITCH - DAVEN - 1220B-16A		
						10	1	CB1	CIRCUIT BREAKER, 5 POLE - HEINEMANN - 100V-12-2-BL		
						11	1	CB2	CIRCUIT BREAKER, 5 POLE - HEINEMANN - 100V-12-2-BL		
						12	1	PL1, PL2	LIGHT - DALCO - 9540B-933		
						13	1	RESET	MS2808B-3C		
						14	1	R1058-9431-14	TERMINAL BLOCK - KULKA - 601-2		
						15	1		KNOB - FELSSENTAL INST. CO. - FMA-2700/252/0-02/BLK		



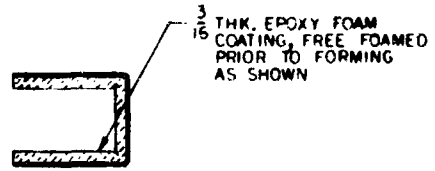
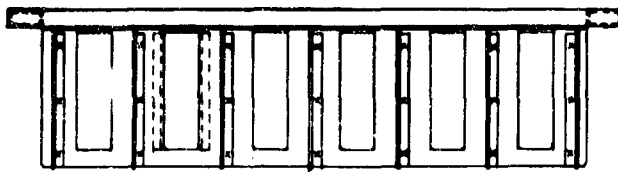
MATERIAL		CARRIER CORPORATION	
APPLIED FORM		This Drawing is the Property of Carrier Corporation. All Rights Reserved.	
SYRACUSE, NEW YORK, U.S.A.		SYRACUSE, NEW YORK, U.S.A.	
CONTROL AND MONITOR PANEL		T.E. ENVIRONMENTAL CONTROL UNIT	
DWR. NO. R1058-9431		DWR. NO. R1058-9431	



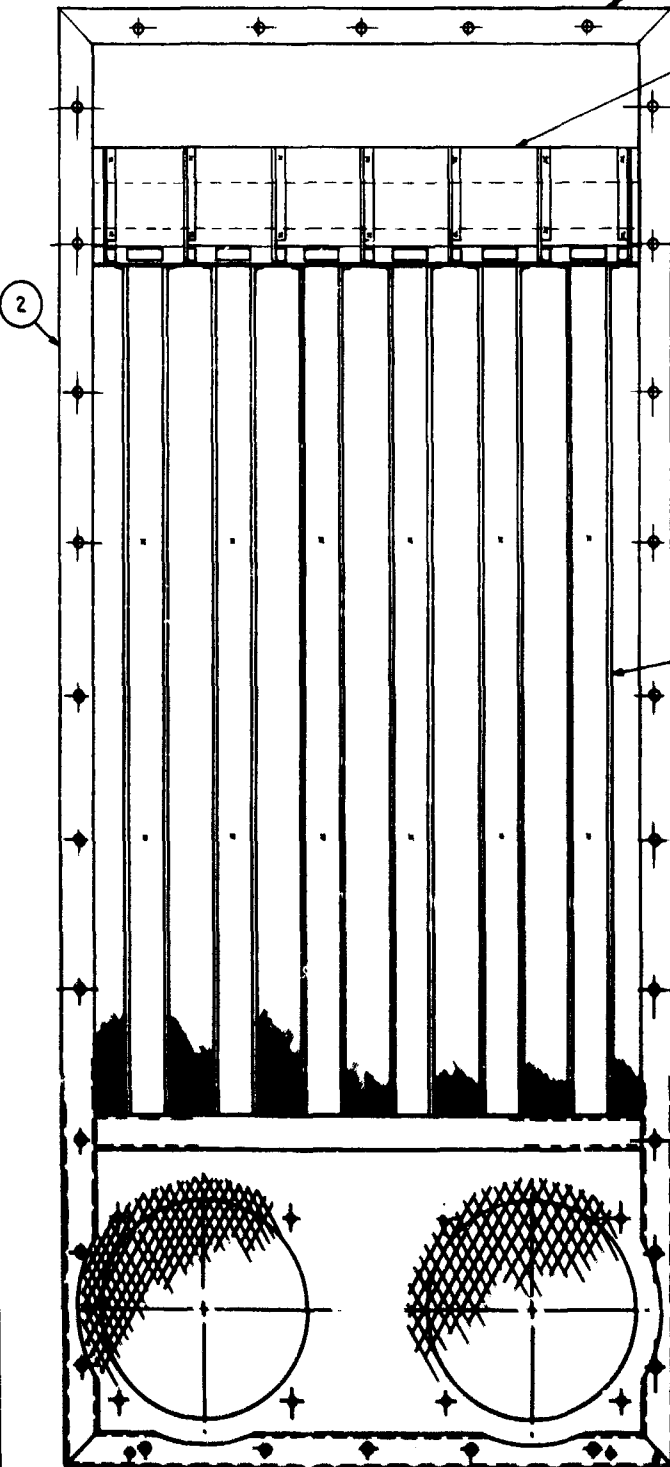


ITEM	QTY	DESCRIPTION	UNIT	REMARKS
1	1	25-BU 5 *PS	1	CAPACITANCE 150 MFD 50V
2	1	CR1, C2	1	CAPACITANCE 100PF 50V
3	1	CR1	1	RELAY - RDM CONTROL #MS25-502
4	1	RR	1	RELAY, REVERSING - KURMAN #262C24DC
5	1	FR, MC	1	RELAY - KURMAN #262C24DC
6	1	MAN	1	RELAY - KURMAN #262C24DC
7	1	LI, L2, L3	1	14 HF WIRE 30 TURNS
8	1		1	ARNOLD CORE #A-254168-2
9	1	TRANS-1	1	TRANSFORMER - REGULUS #Q-1167
10	1	TRANS-2	1	TRANSFORMER - THORDARSON #23V160
11	1	28, 29, 30	1	THYRECTOR DIODE - GE #6RS218AGD6
12	1	SCR1, 2, 3	1	SILICON CONTROLLED RECTIFIER 65V 35A
13	1	DI, DE, DB	1	DIODE - GE #IN3767 65V 35A
14	1	DA, DS, DK	1	DIODE - GE #IN3767 65V 35A
15	1		1	PC BOARD
16	1		1	PC BOARD
17	1	MS 3102A28-11P	1	CONNECTOR
18	1	MS 3102A16-10S	1	CONNECTOR
19	1	R1058-9433-19	1	CONNECTOR, PC ELCO #R-646-1
20	1		1	TERMINAL STRIP - KULKA #G01-3
21	1		1	3/8 X 2 1/2 LG. ROD
22	1		1	11 GA (.090) X 3/8 X 2 1/2 LG ROD SUPPORT
23	1		1	14 GA (.063) X 4 X 5 1/2 LG FIN
24	1		1	3/8 X 3/4 X 2 1/2 LG RECTIFIER MOUNT
25	1	R1058-9429-3	1	.021 THK X 1/2 X 3/4 LG
26	1	R1058-9429-4	1	.021 THK X 3/4 X 3/4 LG
27	1	R1058-9429-6	1	.010 THK X 3/4 X 3/4 LG
28	1	R1058-9433-28	1	11 GA (.090) X 3/8 X 6 LG SUPPORT BRKT
29	1		1	PCB GUIDE - BIRCHER #18B-11-3
30	1		1	11 GA (.090) X 8 X 21' REAR PANEL
31	1		1	14 GA (.063) X 4 X 8' SIDE PANEL
32	1		1	14 GA (.063) X 4 X 8' SIDE PANEL
33	1		1	14 GA (.063) X 4 X 8' PARTITION
34	1		1	14 GA (.063) X 4 X 21' TOP PANEL
35	1		1	14 GA (.063) X 4 X 21' BOTTOM PANEL
36	1		1	14 GA (.063) X 2 1/2 X 17 1/2 PCB BRKT
37	1		1	11 GA (.090) X 3/8 X 3/8 X 2' LG ANGLE
38	1	MS 38206-15	1	4-40 UNC X 3/8 LG MACH SCREW, PAN HD
39	1		1	4-40 UNC X 3/8 LG MACH SCREW, PAN HD
40	1		1	4-32 UNC X 3/8 LG MACH SCREW, PAN HD
41	1		1	6-32 UNC X 3/8 LG MACH SCREW, PAN HD
42	1		1	6-32 UNC X 3/8 LG MACH SCREW, PAN HD
43	1		1	6-32 UNC X 3/8 LG MACH SCREW, PAN HD
44	1		1	6-32 UNC X 3/8 LG MACH SCREW, PAN HD
45	1	MS 21044-MS4	1	4-40 UNC HEX LOCK NUT
46	1	MS 21044-MS4	1	4-32 UNC HEX LOCK NUT
47	1		1	6-32 UNC HEX LOCK NUT
48	1	R1058-9433-47	1	6 SPLIT LOCK WASHER (STEEL)
49	1	MS 20470-MS3	1	3/8 DIA X 3/8 LG RIVET
50	1	MS 20470-MS3	1	3/8 DIA X 3/8 LG RIVET
51	1	MS 20470-MS3	1	6-32 UNC X 3/8 LG MACH SCREW, PAN HD

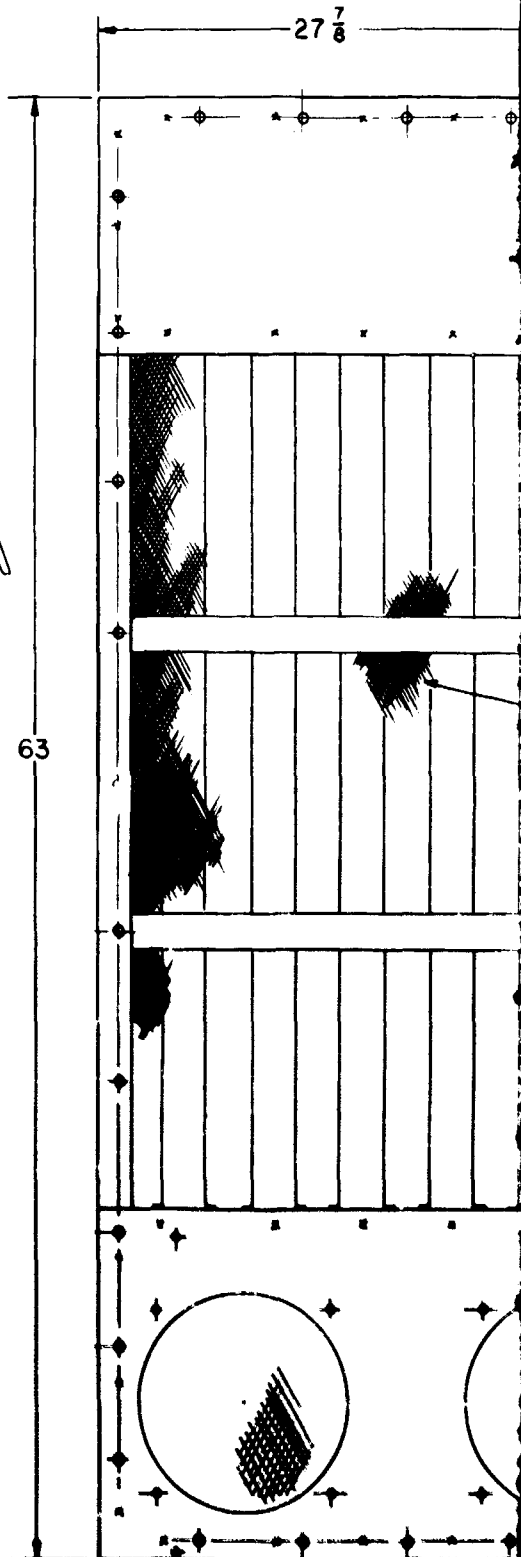
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SECTION A-A

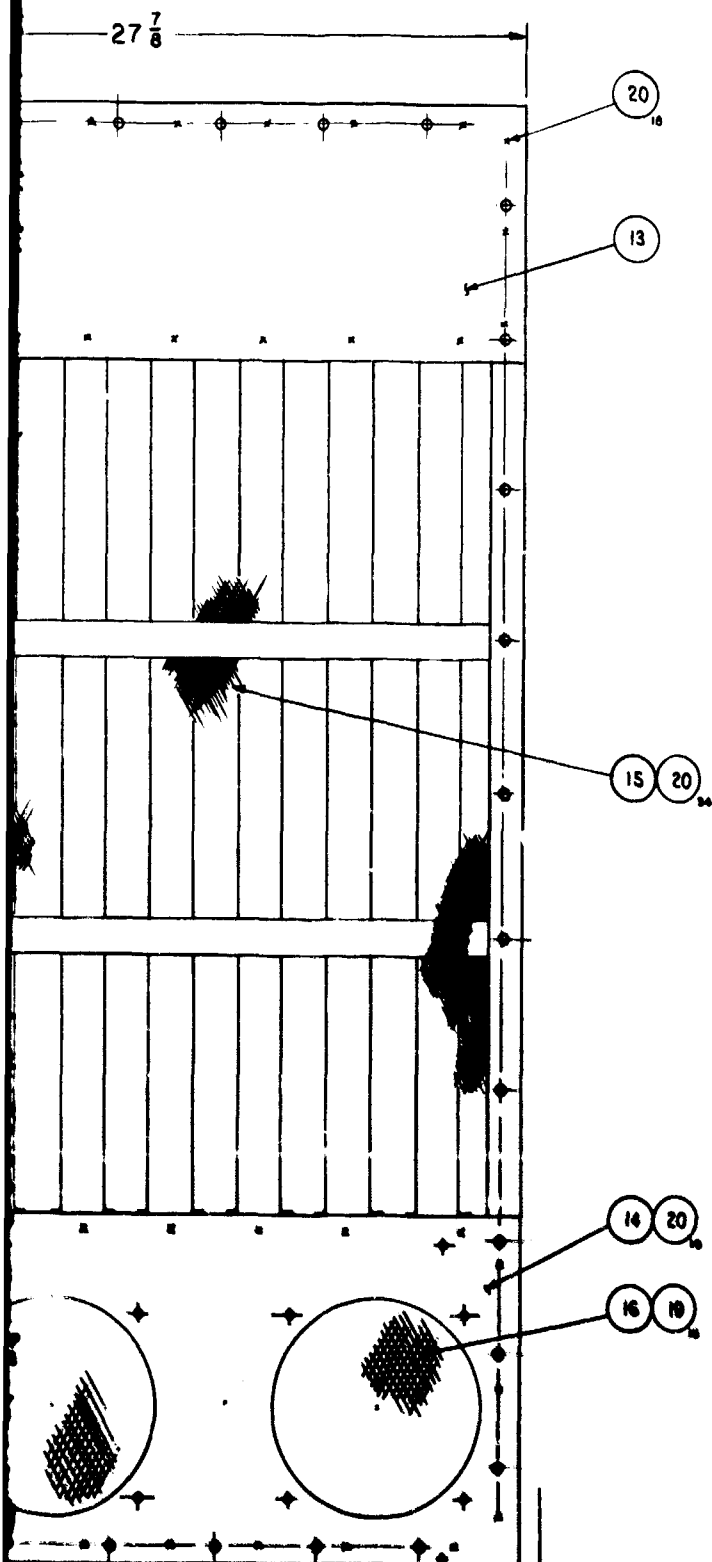


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STRUCTURAL FRAME TO BE OF WELDED CONSTRUCTION

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ITEM	DWG./PART NO.	QTY	DESCRIPTION (FINISHED SIZE)	MATERIAL /PURCHASE
1	RI058-4435	1	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 63 LG.	ALUMINUM 6063-T6
2		1	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 63 LG.	
3		1	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 27 $\frac{1}{2}$ LG.	
4		1	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 27 $\frac{1}{2}$ LG.	
5		2	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 24 $\frac{1}{2}$ LG.	
6		1	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 24 $\frac{1}{2}$ LG.	
7		1	RECTANGULAR TUBE - $\frac{3}{4}$ " \times $1\frac{1}{2}$ " .125 WALL = 24 $\frac{1}{2}$ LG.	
8		1	.063 THK. \times 9 = 24 $\frac{1}{2}$ LG.	ALUMINUM 6061-T6
9		2	.063 THK. \times $1\frac{1}{8}$ " = 3 $\frac{1}{8}$ LG.	
10		1	.063 THK. \times 10 $\frac{1}{2}$ " = 24 $\frac{1}{2}$ LG.	
11		7	.063 THK. \times 5 = 6 $\frac{1}{2}$ LG.	
12		6	.063 THK. \times 12 $\frac{1}{2}$ " = 38 $\frac{1}{2}$ LG. (REFER TO SECTION A-A)	
13		1	.063 THK. \times 11 = 27 $\frac{1}{2}$ LG.	
14		1	.063 THK. \times 15 $\frac{1}{2}$ " = 27 $\frac{1}{2}$ LG.	
15		1	"30 MESH WIRE SCREEN 25 $\frac{7}{8}$ " \times 37 $\frac{1}{2}$ LG.	STAINLESS STL. 304
16		1	EXPANDED METAL - $\frac{1}{4}$ " 18 GA (FLAT) 11" DIA.	STAINLESS STL. 302
17		1	$\frac{1}{4}$ THK. \times 4 $\frac{1}{2}$ " = 24 $\frac{1}{2}$ LG.	2 $\frac{1}{2}$ LB. DENSITY ULTRA FINE CLEAR VINYL OR NEOPRENE COATED BOARD INSULATION EUSTIN BACON CO. OR EQUAL
18		1	$\frac{1}{4}$ THK. \times 2 = 24 $\frac{1}{2}$ LG.	
19	MS20600-B4W2	77	RIVET, BLIND, SELF PUNCHING - $\frac{1}{8}$ DIA.	
20	MS20600-B4W3	96	RIVET, BLIND, SELF PUNCHING - $\frac{1}{8}$ DIA.	PURCHASE

NOTE:

1. BOND INSULATION (ITEM #114) IN POSITION USING
MILM, MINING & MFG. CO. INSULATION ADHESIVE "33 (MIL).

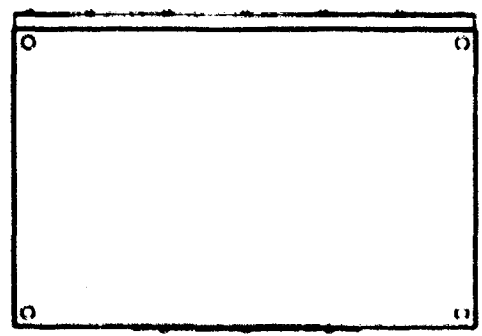
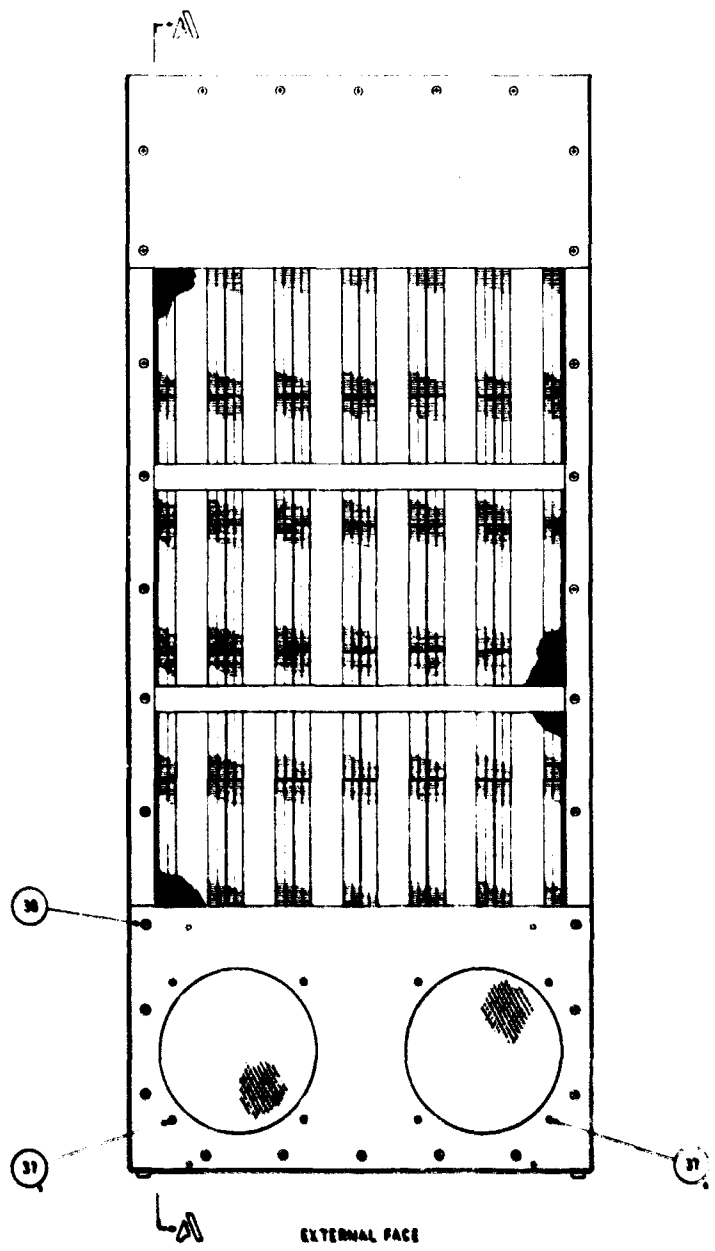
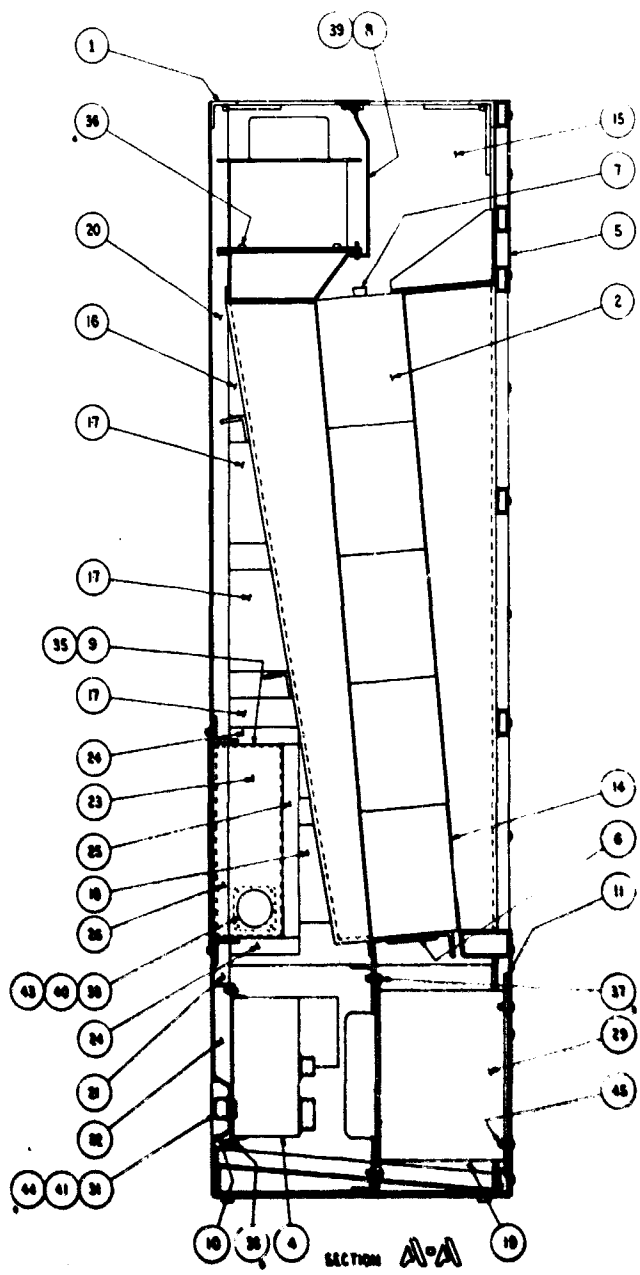
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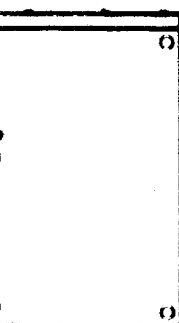
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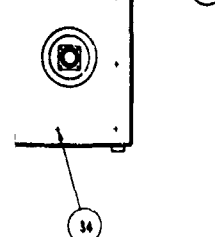
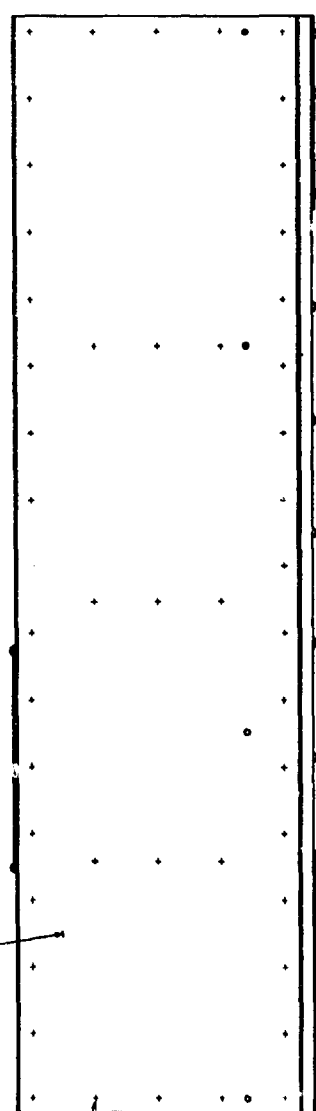
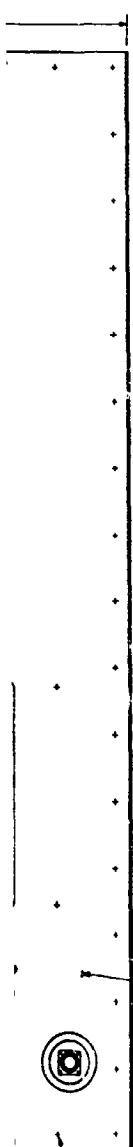
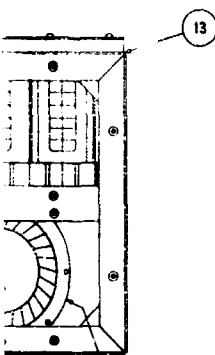


ITEM	QTY	PART NO.	DESCRIPTION (FINISHED SIZE)	MATERIAL / PART NO.
1	1	R1058-9434	FRAME ASSEMBLY	
2	60	R1058-4410	MODULE ASSEMBLY	
3	1	R1058-9431	CONTROL AND MONITOR PANEL	
4	1	R1058-9433	POWER CONVERSION AND CONTROL PACKAGE	
5	1	R1058-4435	ACCESS COVER ASSEMBLY	
6	1	R1058-3457	MODULE RECEPTACLE	
7	12	R1058-2438	JUMPER STRAP	
8	1	R1058-9436-B	0.040 THK. $\times 10 \frac{1}{2} \times 24 \frac{1}{2}$ LG.	ALUMINUM 6061-T6
9	1	-9	0.040 THK. $\times 18 \times 19 \frac{1}{2}$ LG.	
10	1	-10	0.040 THK. $\times 4 \frac{1}{2}$ DIA.	
11	2	-11	THK. $\times 11 \frac{1}{2}$ DIA.	
12	2	-12	THK. $\times 1 \frac{1}{2} \times 63$ LG.	SPONGE RUBBER
13	2	-13	THK. $\times 1 \frac{1}{2} \times 24 \frac{1}{2}$ LG.	ADHESIVE COATED
14	12	-14	THK. $\times 1 \frac{1}{2} \times 36 \frac{1}{2}$ LG.	
15	2	-15	THK. $\times 1 \frac{1}{2} \times 16 \frac{1}{2}$ LG.	
16	2	-16	THK. $\times 5 \times 16 \frac{1}{2}$ LG.	
17	6	-17	THK. $\times 5 \times 16 \frac{1}{2}$ LG.	
18	2	-18	THK. $\times 5 \times 16 \frac{1}{2}$ LG.	
19	2	-19	THK. $\times 12 \times 16 \frac{1}{2}$ LG.	
20	1	-20	THK. $\times 24 \frac{1}{2} \times 36 \frac{1}{2}$ LG.	25 LB. DENSITY ULTRA PURE CLEAR VINYL OR EQUIVALENT COATED BOARD INSULATION "GUTHRIE DESIGN CO." OR EQUIV.
21	1	-21	THK. $\times 2 \frac{1}{2} \times 24 \frac{1}{2}$ LG.	
22	1	-22	THK. $\times 9 \times 24 \frac{1}{2}$ LG.	
23	2	-23	THK. $\times 3 \frac{1}{2} \times 11$ LG.	
24	2	-24	THK. $\times 4 \times 13 \frac{1}{2}$ LG.	
25	1	-25	THK. $\times 11 \times 13 \frac{1}{2}$ LG.	
26	2	-26	THK. $\times 6 \frac{1}{2} \times 11$ LG.	
27	2	-27	0.040 THK. $\times 17 \frac{1}{2} \times 63$ LG.	ALUMINUM 6061-T6
28	1	-28	0.040 THK. $\times 27 \frac{1}{2} \times 63$ LG.	
29	2	-29	FAN - GENERAL DYNAMICS MODEL "8082A"	
30	2	-30	FAN - GENERAL DYNAMICS MODEL "8071A"	
31	1	MS302A-16-100	CONNECTOR, RECEPTACLE AMPHENOL BORG	
32	2	MS302A-16-100	CONNECTOR, RECEPTACLE AMPHENOL BORG	
33	1	MS302A-16-75	CONNECTOR, RECEPTACLE AMPHENOL BORG	
34	140	MS2050Y-0800	RIVET, BLIND, SELF PUNCHING $\frac{1}{8}$ DIA.	
35	6	MS2050H-0800	RIVET, BLIND, SELF PUNCHING $\frac{1}{8}$ DIA.	
36	16	MS3207-063	"0-32 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
37	14	MS3207-064	"0-32 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
38	30	MS3207-085	"0-32 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
39	8	MS3206-027	"0-32 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
40	4	MS3206-040	"0-32 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
41	4	MS3206-14	"0-40 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
42	8	MS3206-13	"0-40 UNC. $\times 1$ LG. MACH. SCREW PAN HD.	
43	4	MS2044-1000	"0-32 UNC. HEX LOCKWUT	
44	12	MS2044-1004	"0-40 UNC. HEX LOCKWUT	
45	8	MS2131-21	WY. BLIND RIVET, PLAT HD, OPEN END "0-32 UNC.	
46	6	R1058-9435-06	2700 - CARBON POLYMER CORR. "125A-22-1A8"	

NOTE:
1. BOARD INSULATION (PUSH-TO-POP) IS NOT-FIRE RESISTANT. BOARD INSULATION CONSIDERED "A" (1000).



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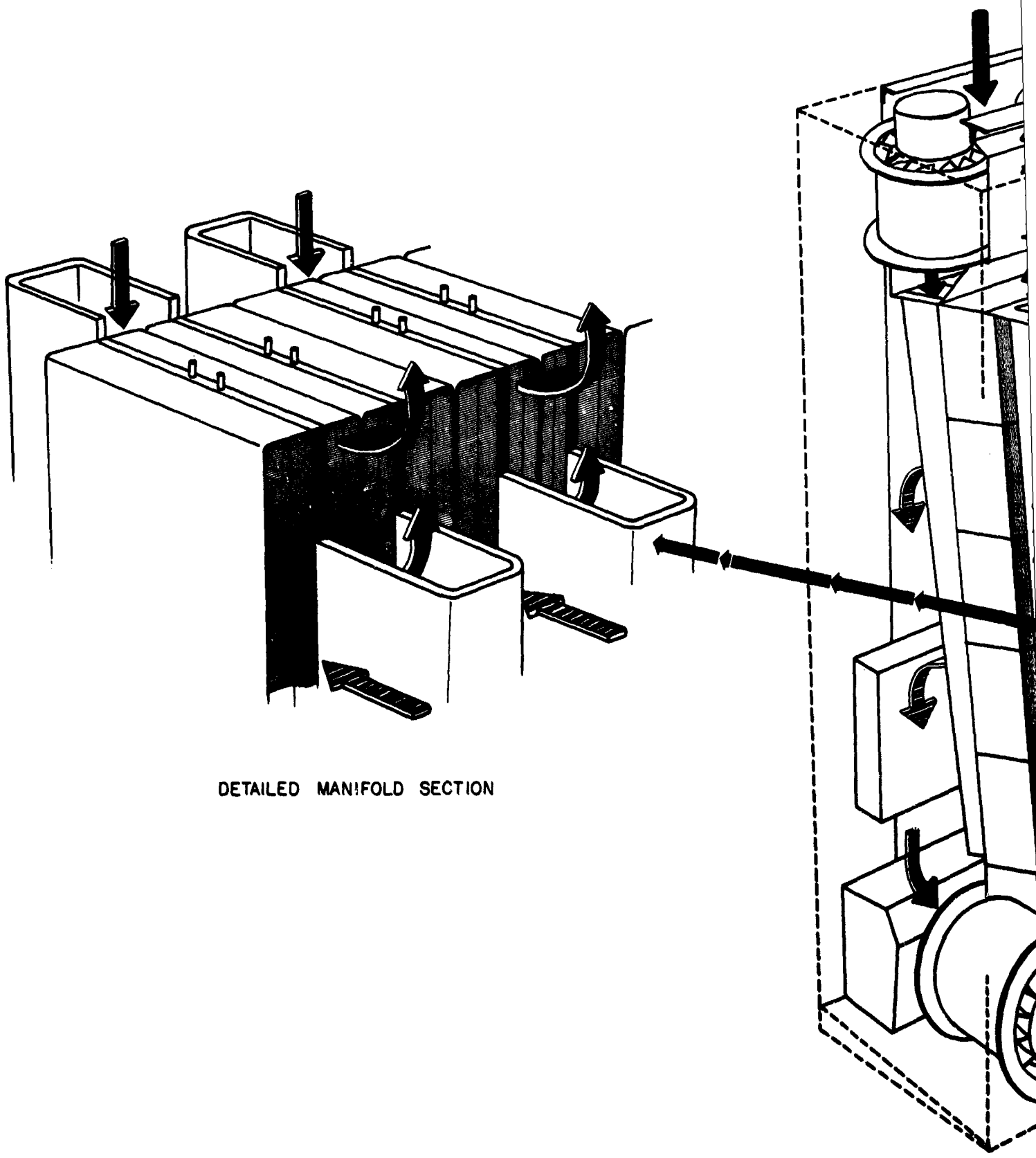


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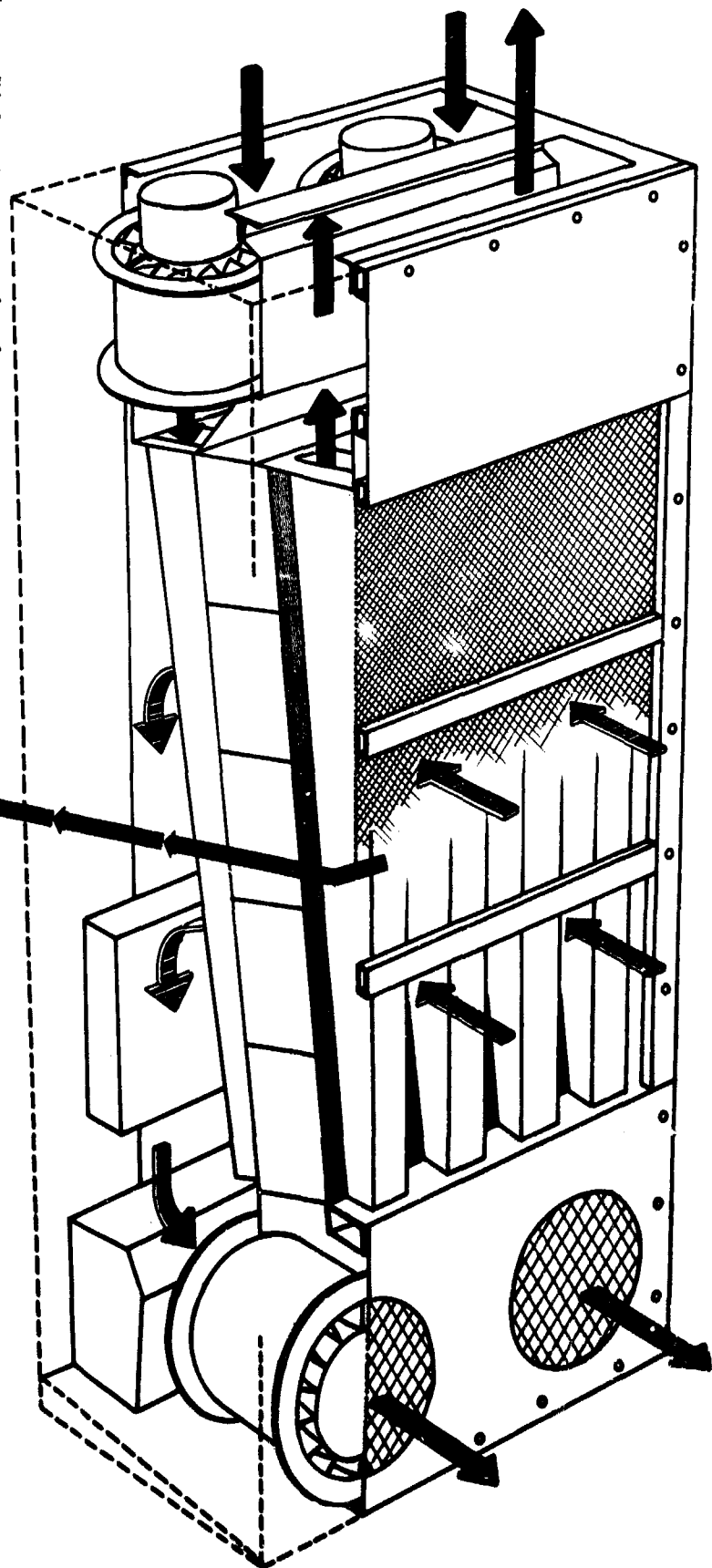
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Q146	9-14-65		
TOTAL PROD. SHIP			
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MATERIAL APPLIED FINISH TO BE SPECIFIED BY THE USER			CARRIER CORPORATION The Carrier is the Property of Carrier Corporation SYRACUSE, NEW YORK, U.S.A.		
FRACTIONS *			DECIMALS *		
SURFACES *			HOLE SPACING *		
HOLE LOCATION *			HOLE LOCATION *		
NON-CUMULATIVE *			NON-CUMULATIVE *		
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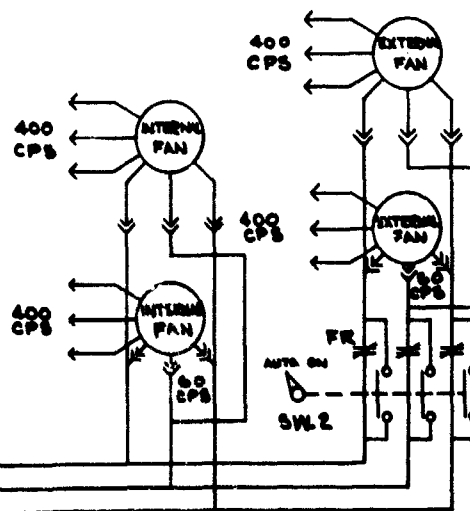
DETAILED MANIFOLD SECTION



UNIT ON ASSY				
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MATERIAL		CARRIER CORPORATION	
APPLIED DESIGN		THE DESIGN IS THE PROPERTY OF CARRIER CORPORATION EVANSTON, ILL. 60120, U.S.A.	
THE DESIGN IS THE PROPERTY OF CARRIER CORPORATION		THE DESIGN IS THE PROPERTY OF CARRIER CORPORATION EVANSTON, ILL. 60120, U.S.A.	
PROPOSED DESIGNED CHECKED DATE BY SCALE		AIR FLOW DIAGRAM FOR T.E. ENVIRONMENTAL CONTROL UNIT	
DWS. NO. R1058-9439			





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MAIN WIRING #14 AWG STRANDED ALPHA No.5119 PVC
 FAN WIRING #16 AWG STRANDED ALPHA No.5117 PVC
 CONTROL WIRING #20 AWG STRANDED ALPHA No.5113 PVC
 THERMISTOR WIRING #20 AWG SHIELDED ALPHA No.2256
 PULSE TRANSFORMER WIRING #20 AWG SHIELDED ALPHA No.2256

SYMBOL	REQD	DESCRIPT
TR19	1	TRANSIST
C1	1	CAPACITOR
C2	1	
C3	1	
C4	1	
C5	1	
C6	1	
C7	1	
C8	1	
C9	1	
C10	1	
C11	1	
C12	1	
CR1	1	RELAY
CR2	1	
RR	1	REVERSING REL
FR	1	FAN RELAY
MC	1	RELAY
MAN	1	
PT1	1	PULSE TRANSFOR
PT2	1	
PT3	1	
TRANS1	1	TRANSFORM
TRANS2	1	
R6	1	POTENTIOMETE
R24	1	
R30	1	
R40	1	
R50	1	
L1	1	INDUCTOR
L2	1	
L3	1	
CB1	1	CIRCUIT BREAK
CB2	1	
PL1	1	MAIN POWER LIG
PL2	1	FAN POWER LIG
SW1	1	SWITCH
SW2	1	
SW3	1	
RESET	1	
VM	1	VOLT METER
TH1	1	N.T.C. THERMISTO
TH2	1	
TH3	1	
R26	1	POTENTIOMETER
R63	1	
R64	1	
TH4	1	N.T.C. THERMISTO
TH5	1	
D23	1	DIODE
D24	1	
PL3	1	RESET LIGHT

[illegible]

Abstract

APPENDIX B

PROCESS SHEETS

- | | |
|--------------------|-----------------------------------------------------|
| R-1058-1149 | Waferizing of Thermoelectric Material |
| R-1058-1225 | Polishing Thermoelectric Encapsulated Wafers |
| R-1058-1162 | Tinning of Thermoelectric Elements |
| R-1058-1185 | RF Bonding of Ceramic Sandwiches |
| R-1058-1299 | Thermoelectric Panel Assembly |
| R-1058-1226 | Foaming of Thermoelectric Panels |

SYN.	REVISION RECORD	DATE	BY	APPD. BY	CH'GD. BY	E.C.R. NO.
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I	Item	E added	12/14/62	JEG	JEG

II Drawing No. added--

Item E 1/24/64 JEC JEC

III Safety Equip. eliminated; alternate method added

9/11/64 JEG JEG

2. General

1. Waferizing machine
 2. Coolant solution for waferizing machine
 3. Dummy encapsulated rod
 4. Diamond blade size $4'' \times .012 \times 5/8$ spindle hole, 180 grit
 5. Thickness gauges
 6. Premounted Norton dressing stick
- Ceramic Block Mounting
1. Encapsulated Thermoelectric material mounted on ceramic block
 2. Small vertical mounting vise

c. Fixture Mounting

1. Thermoelectric material mounted in fixture
2. Adjustable angle vise

B. Cutting Solution Preparation

- a. Bring 750 cc of water to a boil
- b. Add 4 oz. of Dash or equivalent low sudsing detergent
- c. Boil until solution is homogenous
- d. Add this solution to 35 gallons of water in waferizing
- e. Add 2 oz. of household sudsy ammonia. Note: This mix-
quantities.

[illegible]

DO NOT REVERSE THIS DRAWING WITHOUT REFERRING TO DRAWING NO.

PRINT DISTR. Page 1 of 2 QTY.

REVISION RECORD

DATE

BY

APPRO. BY

CH'KD. BY

E.C.R. NO.

1. Circulate solution through wafering machine for 15 minutes.
2. pH of solution should be 8.5 to 9.0.
3. Replace solution after 8 hours.

Wafering Procedure

Set final on height and depth to be used.

4. Install 180 grit diamond saw.
5. Install vertical or adjustable angle vise on magnetic plate, whichever is needed with the used mounting device.
6. Five pieces from every rod used should be checked for thickness and taper with thickness gauge. If incorrect notify supervisor, except index setting if 5 samples show correct setting.
7. Install thermoelectric material in vise. Set saw rate at .9"/minute.
8. Set automatic cut-out switch and saw.
9. Remove waferized material and mount from machine.
10. Redress blade after cutting 50 rods.


Tolerances

Use Drawing No. R1058-2187 for sawing tolerances

Alternate Waferizing Procedure

- a. Mount ceramic block on magnetic chuck or vise, whichever is used.
b. Follow 6-f, 6, and h above.

MATERIAL		CARRIER CORPORATION	
APPLIED FINISH		This Drawing is the Personal Property of Carrier Corporation	
TOLERANCES UNLESS OTHERWISE SPECIFIED		SYRACUSE, NEW YORK, U.S.A.	
FRACTIONS	DECIMALS	TITLE	
±	±	WAFERIZING OF THERMOELECTRIC MATERIAL	
SURFACES	HOLE SPACING	DWG. NO.	
✓ ± IN.	±	R1058-1149	
DR.	NON-CUMULATIVE	Rev. III	
CH'KD.	SCALE	DWG. NO.	
	(90 NOT SCALE DRAWING)	R1058-1149	
		Rev. III	

Operating Procedure		SUPPLIES		None		PROJ. NO. 1058		ENGR. NO.		REV									
						JOB NO.		REQ. NO.											
A. Supplies & Tools Micrometer or Thickness Gauge One Gallon Polyethylene Bottle PR Hoffman PR-1 S.S. Lapping Machine Pellen Paper to fit PR-1 Lapping Machine One Quart Polyethylene Bottle/Speut Bottle Agitator (Drawing #R1058-9180) Weighing Scale D.I. Water Ultra-Sonic Cleaner 99.9% Methanol One Bucket with Handle Set of Carrier's (Drawing #R1058-3202)						APPROVED FOR		ENGRG.		DATE		MFG.		DATE					
						SAMPLE UNIT													
						TRIAL PROD. RUN-"EX."													
						FINAL PROD.													
						Pilot Operations		JEG		1/7/63									
B. Preparing Polishing Compound 1. The one (1) micron Al ₂ O ₃ can be purchased from Geoscience or Linde as certified. 2. Add 1260 gms of the powdered Al ₂ O ₃ to the one (1) gallon polyethylene bottle. 3. Add 1900 cc of deionized water to the bottle and hand agitate the contents thoroughly. 4. Place on rollers of agitator and allow to rotate until ready for use. 5. Keep lid on powder container when not mixing. Room dust will contaminate the Al ₂ O ₃ and cause scratches later on.						TOLERANCES FOR ALL DIMENSIONS ARE ± 0.0005 UNLESS OTHERWISE SPECIFIED													
						ANGULAR ±				MACHINING ±									
						HOLE SPACING & LOCATION ±				NON-CUMULATIVE									
						MANUFACTURED R1058-2187				PURCHASED									
						MATERIAL													
						Encapsulated Thermoelectric Wafer, 1 Micron Al₂O₃, Deionized Water													
						FINISH													
						 <p>THIS DRAWING IS THE PERSONAL PROPERTY OF CARRIER CORPORATION SYRACUSE, NEW YORK, U.S.A. ALL USE IS FORBIDDEN EXCEPT ON ITS WRITTEN CONSENT</p>													
						TITLE													
						POLISHING THERMOELECTRIC ENCAPSULATED WAFERS													
						CAUTION													
						ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.													
						DR.													
						CH.													
						DWG. NO.													

Operating Procedure						SUPERGRUES						None					
C. Preparing PR-1 S.S. Lap.																	
<ol style="list-style-type: none"> 1. Unscrew dust cap and remove dust cap lid. 2. Insert the five conditioning gears. 3. Replace dust cap lid and screw dust cap into position. 4. Secure some 26.5 micron lapping compound mixture, used for finishing copper strips (Dwg. No. R1058-1196). Shake bottle vigorously and pour part of contents over the conditioning gears. Do not waste the compound however. 5. Set top lapping plate into position and set against sustaining bar. 6. Turn on main switch, then reostat switch. Wait 10 seconds and then start machine by slowly turning the reostat to full power. 7. Add vigorously mixed lapping compound through the small openings in the top of the upper plate. Continue conditioning and adding the compound until all scratches are removed from both the upper and lower plates. 8. When conditioning has been completed, remove the conditioning gears and clean in Triclene D. Wrap in paper and store. 9. Clean the machine thoroughly with Triclene D. All traces of oil and lapping compound must be removed from the upper gear mechanism and plates. The Triclene D will drain into the bucket provided. 																	
REQ. USED ON ASSEN.						REVISION						DATE BY APP'D BY CHECKED BY					

PROJ. NO. 1058

JOB NO.

ENGR. NO.

REG. NO.

APPROVED FOR	ENGRG.	DATE	MFG.	DATE
SAMPLE UNIT				
TRIAL PROD. RUN-"EX."				
FINAL PROD.				
Pilot Operations JEG 1/7/63				
TOLERANCES FOR ALL DIMENSIONS ARE ± 0.0005 UNLESS OTHERWISE SPECIFIED				
ANGULAR ±	MACHINING ±			
HOLE SPACING & LOCATION ±			NON-CUMULATIVE	
MANUFACTURED R1058-2187	PURCHASED			

MATERIAL

Encapsulated Thermoelectric Wafers,
1 Micron Al2O3, Deionized Water

FINISH

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TITLE

POLISHING THERMOELECTRIC
ENCAPSULATED WAFERS

CAUTION

ALL DIMENSIONS GIVEN IN INCHES.
DO NOT SCALE DRAWING.

DR.

CH.

SCALE

DWG. NO.

R1058-1225

DWG.


R1058-1225

REV


DO NOT REVISE THIS DRAWING WITHOUT REFERRING TO DRAWING NO.

R1058-2187


pg 2 of 5

Operating Procedure		SUPERSEDES		None					
<p>around the holes.</p> <p>5. Pour one quart of deionized water on the paper of each plate. Set polishing carriers into position and lower top plate into place. Secure against sustaining bar.</p> <p>6. Pour part of contents from the one (1) gallon bottle into a one (1) quart bottle/spout. Add compound to the plates via the holes heretofore described.</p> <p>7. Start the machine using afore-described procedure.</p> <p>8. Run the machine for 15 minutes adding compound periodically.</p> <p>9. Machine is now ready to polish the thermoelectric elements.</p> <p>10. If a crash occurs and the paper is torn, repeat this procedure, items D 1 - 9, using deionized water instead of Tricelene D for cleaning.</p> <p><u>E. Polishing Thermoelectric Encapsulated Wafers</u></p> <p>1. Each period the machine is used for the first time that day or when the paper appears dried out, pour deionized water over both plates thoroughly wetting the pellon paper.</p> <p>2. Set the carriers into position, equally along the gear rims.</p> <p>3. Place elements or wafers to be polished into the holes of the carriers.</p>		PROJ. NO. 1058		ENGR. NO.					
		JOB NO.		REQ. NO.					
		APPROVED FOR	ENGRG.	DATE	MFG.	DATE			
		SAMPLE UNIT							
		TRIAL PROD. RUN-"EX."							
FINAL PROD.									
Pilot Operations	JEG	1/7/63							
TOLERANCES FOR ALL DIMENSIONS ARE \pm 0.0005 UNLESS OTHERWISE SPECIFIED									
ANGULAR \pm	MACHINING \pm								
HOLE SPACING & LOCATION \pm		NON-CUMULATIVE							
MANUFACTURED R1058-2187		PURCHASED							
MATERIAL		Encapsulated Thermoelectric Wafers, 1 Micron Al ₂ O ₃ , Deionized Water							
FINISH									
<div style="text-align: center;"><p>THIS DRAWING IS THE PERSONAL PROPERTY OF CARRIER CORPORATION SYRACUSE, NEW YORK, U.S.A. ALL USE IS FORBIDDEN EXCEPT ON ITS WRITTEN CONSENT</p></div>									
					TITLE				
					POLISHING THERMOELECTRIC ENCAPSULATED WAFERS				
CAUTION ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.									
DR.				SCALE					
CH.									
DWG. NO.		R1058-1225							

REQ.	USED ON ASSEM.	REVISION	DATE	BY	APPROV BY	CHECKED BY

SUPERSEDES		PROJ. NO. R1058		ENGR. NO.	
Operating Procedure		JOB NO.		REQ. NO.	
Hand Tinning		APPROVED FOR		ENGRG. DATE	
A. Equipment		SAMPLE UNIT		MFG. DATE	
1. Tweezers		TRIAL PROD. RUN-"EX."			
2. Scott paper towels		FINAL PROD.			
3. Safety glasses		Pilot Operation		AFK 11/1/68	
4. Redford Corp. Model G-200A ultrasonic generator and ultrasonic soldering pot Model 1147		TOLERANCES FOR ALL DIMENSIONS ARE ± UNLESS OTHERWISE SPECIFIED			
5. Propane torch		ANGULAR ±		MACHINING ±	
6. Solder: 59% Bi; 39% Sn; 2% Sb (see Drawing R1058-1197)		HOLE SPACING & LOCATION ±		NON-CUMULATIVE	
B. Preparing Solder Pot		MANUFACTURED		PURCHASED	
1. Set the solder pot control dial at 5+. This should give a solder temperature of 440 + 10°F.		MATERIAL		Solder per Drawing R1058-1197	
2. Using a propane gas torch, melt the BiSn solder into the pot, until the level of the molten material is just above the ultrasonic heads.		TE Elements per Drawing R1058-2187			
3. Scrap off any oxidation residue which might have formed during the solder melting process.		FINISH			
4. Set the generator power dials at 50.				THIS DRAWING IS THE PERSONAL PROPERTY OF CARRIER CORPORATION SYRACUSE, NEW YORK, U.S.A. ALL USE IS FORBIDDEN EXCEPT ON ITS WRITTEN CONSENT	
5. Temperature on the built-in dial thermometer should read approximately 400°F, 50°F less than actual temperature of the molten solder.					
6. One at a time, tune the transducers. Rush the foot switch and adjust the phase dial for the highest pitch available. Shut off this transducer and tune the other.		TITLE		Tinning of Thermoelectric Elements	
7. Pick up an element with the tweezers, holding it vertically and the narrow side at right angle to the front of the pot. Insert the element between the two transducer heads and measure remaining space between the elements and the heads.					
8. Adjust, by loosening the screws in the holding bracket, to give a spacing of 20 mils more than the elements to be tinned are thick. Tighten screws.		CAUTION		ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.	
REQ. USED ON ASSEMBLY		DR.		SCALE	
REVISION		CH.			
Item C-2 Call Engineer		DWG. NO.		R1058-1192 Rev. III	
Item C-1 Fin, four sec.					
Item A-6 added					
Item C and D added					
I Entire					
DATE		APPROVED BY		CHECKED BY	
11/24/64		JEG		JEG	
7/8/63		JEG		JEG	
5/7/63		JEG		JEG	

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SUPERVISOR		PROJ. NO. R1058		ENGR. NO.	
		JOB NO.		REQ. NO.	
		APPROVED FOR	ENGRG.	DATE	MFG.
		SAMPLE UNIT			
		TRIAL PROD. RUN-"EX."			
		FINAL PROD.			
		TOLERANCES FOR ALL DIMENSIONS ARE ± UNLESS OTHERWISE SPECIFIED			
		ANGULAR ±	MACHINING ±		NON-CUMULATIVE
		HOLE SPACING & LOCATION ±		PURCHASED	
		MANUFACTURED			
		MATERIAL			
		FINISH			
		<div></div> <p>THIS DRAWING IS THE PERSONAL PROPERTY OF CARRIER CORPORATION SYRACUSE, NEW YORK, U.S.A.</p> <p>ALL USE IS FORBIDDEN EXCEPT ON ITS WRITTEN CONSENT</p>			
		TITLE Tinning of Thermoelectric Elements			
CAUTION		ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.			
DR.				SCALE	
CH.					
DWG. No.		R1058-1192		Rev. III	

9. Inspect the element just used for setting the heads and if the epoxy has expanded a crack, discard the piece.					
C. <u>Tinning</u>					
1. Tinning may now begin by picking up an element as described in B-7. Insert element between the heads and push foot switch. Slowly move element while under the solder, back and forth, always remaining within the area of the two heads. After four seconds, lift piece from solder and then remove foot from switch.					
2. Inspect both sides of the element and if tinning is not complete to the outer edges, call Engineer.					
3. Lay tinned element on a clean towel. There is no need to wait until solder has solidified.					
4. When tinning has been completed, leave solder pot "on" at temperatures heretofore set.					
D. <u>Maintenance of Pot</u>					
1. Periodically, sample the liquid and have chemical analysis performed to ascertain changes in composition.					
2. If there is an indicated change in the Bi, Sn and Sb content of more than 5%, the solder should be removed from the pot and discarded.					
3. To remove solder, set the entire pot assembly on a stand or blocks about 6" off the table. Turn screw in rear of pot and catch molten solder in a freezer cup (two may be needed). When completed return emptying screw to normal.					
REQ.	USED ON ASSEM.	REVISION		DATE	BY
					APPROD BY
					CHECKED BY

DO NOT REVISE THIS DRAWING WITHOUT REFERRING TO DRAWING NO.

Operating Procedure		SUPERSEDES		none	
A. Equipment and Supplies					
2 1/2 kw Induction Heater, Lepel or Equivalent					
'Automatic Fixturing, Drawing R1058-9175 and -9203					
Tweezers					
Flux, Kester 1544 diluted 1:1 with Kester 104 Thinner					
Tin Plated Copper Pieces and Ceramic Wafers per drawings.					
B. Start Up					
1. Turn on cooling water to RF generator.					
2. Adjust air supply to hold down flixture to 20-25 psi.					
3. Make sure cooling air valves are on.					
4. Set start switch on "push button".					
5. Turn on RF generator power. Wait 10 minutes for generator to warm up.					
6. Set start switch on "foot" switch control.					
7. Push foot switch and set grid to read 250 on the meter provided. Power dial to be set at full scale.					

PROJ. NO. R1058	ENGR. NO.	REV III		
JOB NO.	REQ. NO.			
APPROVED FOR	ENGRG.	DATE	MFG.	DATE
SAMPLE UNIT				
TRIAL PROD. RUN-"EX."				
FINAL PROD.				
Pilot Operations	JEG	2/8/63		
TOLERANCES FOR ALL DIMENSIONS ARE \pm 1%				
UNLESS OTHERWISE SPECIFIED				
ANGULAR \pm	MACHINING \pm			
HOLE SPACING & LOCATION \pm	NON-CUMULATIVE			
MANUFACTURED \times	PURCHASED			
MATERIAL copper straps, and spacers, Carrier Drawing R1058-3181, ceramics, Carrier Drawing R1058-1141 or 1166				
FINISH				




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TITLE
RF BONDING OF CERAMIC SANDWICHES

CAUTION		ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.	
DR.			SCALE
CH.			
DWG. NO.	R1058-1185	REV. IX	

1	Type flux used	7/8/63	JEG	JEG	CHECKED BY		
		1/24/64	REZ	JEG			
		9/19/64	JEG	JEG			
2		C-5 "steking" to "vipe"		DATE		BY	APPROD BY
3		B-2 "28 to 20-25 psi"					
C-13		Use of tweezers					
REVISION							

Operating Procedure		SUPERSEDES	none
C. Operating Procedure			
<p>1. Select the sliding fixture, 12 or 7 mm type, to be used.</p> <p>2. Hold down retaining pin and slide the fixture into slot of the larger retaining fixture.</p> <p>3. With slide in place release retaining pin. Move slide back and forth to check for freedom of movement and binding.</p> <p>4. Move slide to either left or right and set one copper spacer into each of two counter sunk spaces provided. Use tweezer to handle the spacers.</p> <p>5. With tweezers, pick up a ceramic wafer, dip in flux, wipe off excess; then set into counter sunk slot on top of the previous positioned spacer. Repeat for second wafer.</p> <p>6. Again using tweezers, set one copper strap into counter sunk slot on top of the fluxed ceramic wafer. Repeat for second wire.</p> <p>7. When sure all three components of each slot are in proper position, move the sliding fixture in the opposite direction until it stops. The ceramic-copper sandwich components are now located directly under the top portion of the RF coil.</p> <p>8. Push the foot switch. The RF coil will become active and heating of the copper pieces is automatic. At the same time, the three fingered holder will push downward through the coil and hold the sandwich components into position firmly.</p>			
REQ.	USED ON ASSEM.	REVISION	CHECKED BY

PROJ. NO. R1058		ENGR. NO.	
JOB NO.		REQ. NO.	
APPROVED FOR,	ENGRG.	DATE	MFG.
SAMPLE UNIT			
TRIAL PROD. RUN-"EX."			
FINAL PROD.			
Pilot Operations	JEG	2/8/69	
TOLERANCES FOR ALL DIMENSIONS ARE ± 1%			
UNLESS OTHERWISE SPECIFIED			
ANGULAR ±	MACHINING ±		
HOLE SPACING & LOCATION ±	NON-CUMULATIVE		
MANUFACTURED X	PURCHASED		
MATERIAL copper straps and spacers, Carrier Drawing R1058-3181, ceramics, Carrier Drawing R1058-1141 or 1166			
FINISH			
<div style="text-align: center;"></div>			
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TITLE			
RF BONDING OF CERAMIC SANDWICHES			
CAUTION ALL DIMENSIONS GIVEN IN INCHES. DO NOT SCALE DRAWING.			
DR.			SCALE
CH.			
DWG. No.	R1058-1185	Rev.	III

R1058-1185

DWG. NO.

REV III

DO NOT REVISE THIS DRAWING WITHOUT REFERRING TO DRAWING NO. R1058-3181, 1141, 1166, 9175, 9203.

Operating Procedure		SUPersedes		none																																																												
<p>9. The induction heating cycle will continue for the period set on the automatic timer, which for components shown on Carrier drawing R1058-3181 is approximately 16 seconds at a grid setting of 250.</p> <p>10. Immediately upon conclusion of the heating cycle (red light goes off), the compressed air is turned automatically on and cools the sandwich to a point below the melting point of the plated tin. This time cycle may vary between the 12 and 7 mm pieces and may also be a function of the compressed air temperature. The cycle can be adjusted on the clock-timer provided in the circuit.</p> <p>11. Immediately upon completion of the cooling cycle, the three fingered holder will rise and slide can now be moved.</p> <p>12. Move the slide in the opposite direction until the sandwiches are directly over the discharge air holes.</p> <p>13. Push foot switch provided and an air blast will push the hot sandwiches out of their slots into a trough and finally into a metal container where they will finally cool to room temperature. Sandwiches may also be removed with tweezers, if foot switch is not used.</p> <p>14. After the operator has become familiar with the foregoing procedure, he then can load the empty side of the fixture while the full side is going through the melting and cooling cycles. In this manner, a new set of sandwich components are always ready for bonding as the completed ones are removed by air pressure from the fixture.</p> <p>15. When the machine is not in use, the start switch should be set on "push button" to avoid accidental tripping of the foot switch</p>		<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> <td style="width:10%;"></td> </tr> <tr> <td colspan="8" style="text-align: center;">REVISION</td> <td style="text-align: center;">DATE</td> <td style="text-align: center;">BY</td> </tr> <tr> <td colspan="8"></td> <td></td> <td></td> </tr> <tr> <td colspan="8"></td> <td></td> <td></td> </tr> <tr> <td colspan="8"></td> <td></td> <td></td> </tr> <tr> <td style="width:10%;">REQ.</td> <td colspan="8" style="width:70%;">USED ON ASSEM.</td> <td style="width:10%;">APPRO'D BY</td> <td style="width:10%;">CHECKED BY</td> </tr> </table>												REVISION								DATE	BY																															REQ.	USED ON ASSEM.								APPRO'D BY	CHECKED BY
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DR.		SCALE	
CH.			

DWG. No.	R1058-1185 Rev. III
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SYM.	REVISION RECORD	DATE	BY	APPD. BY	CH'KD. BY	E.C.R. NO.
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A. Operating Supplies and Equipment

1. Tweezers (Teflon coated)
2. Transite matrix fixtures, RL058
3. Mylar lattice cut and assembled for type panel to be fabricated
4. Kester 1429 flux
5. Flux brush, standard size with bristles cut to 1/4"
6. Scott paper towels
7. Small beaker
8. 50K Westinghouse PF generator or equivalent with coil
9. Compressed dry air supply
10. 1/16" aluminum plate cut to panel size

B. Assembly Procedure

1. Turn on generator and allow to warm up for 15 minutes
2. Set lattice into position on matrix plate and remove top cross pieces
3. Lay into position, ceramic sandwiches on matrix plate in configuration equal panel being assembled, spacer side down. Do not mix sandwiches, premeasured to tolerance of .0005" and previously separated into size lots
4. Set lead strap into position
5. Using Teflon coated tweezers, pick up elements vertically, dip in flux and then blot excess runoff on Scott towel

USED ON ASSY. ALL R1058 AUTHORIZATION NO. _____				CARRIER CORPORATION SYRACUSE, NEW YORK, U.S.A.			
MANUFACTURED _____				TITLE THERMOELECTRIC PANEL ASSEMBLY (RF BONDING)			
APPROVED FOR	ENGR.	DATE	WFG.	This Drawing is the Personal Property of Carrier Corporation All Use Is Forbidden Except On Its Written Consent			
Pilot Oper.	APK	4/21/64					
TRIAL PROD. RUN				MATERIAL TE Wafers - R1058-2187 Ceramic Sandwiches - R1058-5181			
FINAL PROD.				APPLIED FINISH TOLERANCES UNLESS OTHERWISE SPECIFIED			
				FRACTIONS	DECIMALS	ANGLES	
				±	±	±	
				SURFACES	HOLE SPACING	HOLE LOCATION	
				✓	±	±	
				NON-CUMULATIVE			
				DR.		SCALE	
				CH'ED.		(DO NOT SCALE DRAWING)	
				DWG. NO. R1058-1299			

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PRINT DIST. Page 1 of 3 QTY.

6. Lay top cross pieces on lattice and fit into position.
7. Left lead strap is always negative. First element will therefore be p-type.
8. Starting with p-type, set all p-type elements into position, alternating checkerboard style.
9. Set all n-type elements into position in the remaining alternate spaces.
10. Adjust centering of each element with tweezers.
11. Holding the ceramic sandwich, strap side down, with tweezers, lower into the flux wetting on the strap portion.
12. Set ceramic sandwiches into position on top of elements.
13. Set top of matrix plate on unbonded panel. Care must be used to fit the rubber cushions between the lattice sections. Check to assure a good fit before inserting the small nylon screws or bolts into transits.
14. Set nuts on bolts. Tighten nuts in center band tight. Tighten remaining nuts.
15. With a socket wrench, draw nuts up snug.

USED ON ASBY.		AUTHORIZATION NO.		MATERIAL		CARRIER CORPORATION	
MANUFACTURED	DATE	DATE	DATE	APPLIED FINISH		This Drawing is the Personal Property of Carrier Corporation	
APPROVED FOR	DATE	DATE	DATE	TOLERANCES UNLESS OTHERWISE SPECIFIED		All Use Is Forbidden Except On Written Consent	
TRIAL PROG. RUN				FRACTIONS	DECIMALS	ANGLES	SYRACUSE, NEW YORK, U.S.A.
FINAL PROG.				SURFACES	HOLE SPACING	HOLE LOCATION	
				✓	±	±	TITLE
				NON-CUMULATIVE			Thermoelectric Panel Assembly (REF BONDING)
				OR.	SCALE		DWG. NO. R1058-1299
				CH'KD.	(DO NOT SCALE DRAWING)		


SYM.	REVISION RECORD	DATE	BY	APPD. BY	CH'KD. BY	E.C.R. NO.

C. Bonding

1. Tune generator to predetermined settings.
2. Set timer to appropriate setting.
3. Place and center panel assembly in coil.
4. Push "on" button.
5. After set time interval has elapsed and power is off, remove panel from coil. Cool with forced air directed between transite plates for approximately 2 minutes.

D. Calibrating RF

Various output and time cycles will differ as change in panel sizes occurs from time to time. Check operating manual for establishing new settings.

USED ON ASSY.		MATERIAL		CARRIER CORPORATION		This Drawing is the Personal Property of Carrier Corporation  All Use Is Forbidden Except On Its Written Consent	
AUTHORIZATION NO.		APPLIED FINISH		TITLE		SYRACUSE, NEW YORK, U.S.A.	
MANUFACTURED		TOLERANCES UNLESS OTHERWISE SPECIFIED		THERMOELECTRIC PANEL ASSEMBLY		(RF BONDING)	
APPROVED FOR		FRACTIONS ± DECIMALS ± ANGLES ± SURFACES ± HOLE SPACING ± HOLE LOCATION ± ✓ MIN. NON-CUMULATIVE		DWG. NO.		R1058-1299	
TRIAL PROD. RUN		DR.		SCALE		(DO NOT SCALE DRAWING)	
FINAL PROD.		CH'KD.					

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SYM.	REVISION RECORD	DATE	BY	APPD.	CHKD.	E.C.R.
				BY	BY	NO.

C. Foaming of Panel

1. Set panel, hot side up, on locating block covered with Saran wrap
2. Pour about one-third of mixed foam on bottom (hot side) of panel
3. Set mold on top of panel
4. Invert panel and mold to right side up
5. Remove locating block
6. Pour remainder of foam, quickly, on panel
7. Lay rubber pad on top of foam covered panel
8. Lay weight on rubber pad
9. After foaming ceases and foam is hard to the touch, set panel into oven at 150°F for 10 minutes to cure
10. Remove panel from oven, and remove mold from foamed panel
11. Cut away excess flash with a sharp instrument

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5. AUTHOR(S) (Last name, first name, initial) Rudelson, G.D.; Gable, G.K.; Beck, A.A.			
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13. ABSTRACT A detailed engineering design is presented for a 24,000 Btu/hr Thermoelectric Environmental Control Unit. System design is based on an optimization analysis performed on an analog computer. Procedures followed and results obtained are described. Twelve design parameters were optimized for minimum weight and maximum efficiency. System is 28 in. wide x 18 in. deep x 63 in. high, weighs 380 lbs. and operates at an overall C.O.P. (including fans) of 1.12 with a net cooling capacity of 24,000 Btu/hr at design operating conditions. Dual frequency (60 and 400 cps) fans are used. Power rectifier furnishes 3 phase, full wave d-c power without voltage transformation. Modulated capacity control is provided from full cooling to full heating as required by system load. The design is based on air-to-air heat exchange utilizing aluminum heat transfer surface. Operating instructions, maintenance procedures, manufacturing procedures and cost analysis information are included. Recommendation is made to develop a prototype unit.			

14. KEY WORDS		LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
Thermoelectric Heat Pump							
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